Appropriate Sanitation for Urban Areas

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1. INTRODUCTION

Summary

Field study

To study the problems of implementing sanitation technologies in Africa trips were made to Kenya, Tanzania, Zambia, Ghana and Nigeria in 1975-1978. Numerous problems were experienced within fields of project planning, project appraisal, project implementing and operation and maintenance of the implemented projects. It appeared that it was more complicated to solve the sanitation problems for the urban low and middle income groups than for the rural areas and the urban high income areas. It was therefore decided to concentrate this report on the urban areas with special reference to Africa.

Report

Besides describing the background for selecting an appropriate sanitation technology an attempt is made to give a method of relating investments directly to the household income. Also it is suggested that everybody must financially contribute to the solution of the sanitary problems the overall objective being the improvement of the public health.

Project appraisal is described and an approach to appraise benefits accrued is included. This approach (AIC-method) also indicates how cost effective investments are made.

To illustrate the suggested approach to investments in sanitation schemes and the appraisal of alternative solutions, a case study was applied to the provincial capital Morogoro in Tanzania. This constitutes a typical african complex urban area. The case study discusses three alternative sanitation schemes based on equal size investments. The available investments are derived from annual instalments which are affordable to the households. The appraisal of the three alternatives illustrate the the importance of considering the whole complex urban area when appraising a sanitation scheeme.

Comprehensive background material was available for the case study including a preliminary design report on sewerage and low cost sanitation for Morogoro. The detailed background material made it possible to consider physical, socio-economic and socio-cultural conditions when selecting sanitation technologies.

It has been concluded that even for a country belonging to the low income group it is possible to finance a sanitation scheme based on affordable incomes, providing at least a minimum service level.

Further it has been concluded that the whole complex urban area must be considered when appraising and planning a sanitation scheme.

It is suggested that not only implementation of sewerage system but also the implementation of on-site disposal systems should be a government (or municipal) responsibility and not left to the users which has been and still is common practice.

Objectives

The objectives of this study are:

- to review current implementation of sanitation technologies in Africa through a field study,

- to establish the financial capability of an urban community to solve their sanitation problems. Emphasis is placed upon the principle that an urban community must be able to financially afford a proposed sanitation scheme,

- through a case study to illustrate a method of appraising alternative sanitation schemes considering the whole of a complex urban area in Africa.

  The case study should be made on an urban area typical (in general terms) for Africa. As many aspects as possible should be considered within the fields of socio-culture, economy, environment and technology.

Field Studies

General

A field study of implemented sanitation technologies was carried out in East and West Africa. The purpose was to study:

- Transfer of advanced sanitation technologies
- Less advanced sanitation technologies
- Efficiency (or existance) of sanitation planning
- Design criteria for the sanitation technologies
- Operation and maintenance
- Social constraints.

This was accomplished through discussions with local technicians and politicians. The infrastructure, particularly sanitation technologies, was studied in detail. All data and information was collected and analysed to be used in this report. Numerous photos were taken, of which a few are shown in this chapter to illustrate the subjects discussed.

This follow-up study of transferred (and moderated) technology which has been in implementation for years, is of vital importance to future successful technology aid to the developing countries. Previously only technology type and the financing problem have been considered, whereas it is by now obvious that only by including social, economic and environmental considerations will future technology aid (experts or equipment) reach the intended objectives.

Also it is by now obvious that only by organizing and implementing a well-functioning operation and maintenance can the long-term use of a system be secured.

Transfer of Advanced Technologies

In studying advanced technologies introduced from e.g. Europe it appeared that they had often been transferred without considering the completely different conditions and criteria prevailing in the receiving country.

Photos 1 and 2 show a bio-filter plant which was malfunctioning due to filter media and digester being clogged by sand and fat. Malfunctioning also occurred because of undersized pipes. The filter media were thorougly washed now and then, but this made the biofilter work properly only for 2 weeks. The effluent is now treated additionally in ponds (photo 3), and the discharge is of a reasonable quality. Still this is due to the ponds and not to the bio-filter plant which may in fact be bypassed in future.

Photos 4 and 5 show a manually and a mechanically operated screen, which are parallel-mounted. Only the manually operated screen has ever been used. The reason is that no spare parts are available for the mechanical screen.

Photos 6 and 7 show advanced technology which was found to be performing well. The surface-aerator on photo 6 was installed at a university thus being professionally supervised.

The jet cleaner on photo 7 was run by a well-trained crew.

Less Advanced Sanitation Technologies

A visit was paid to the outskirts of Dar es Salaam where compost toilets have been constructed (photos 9, 10 and 11). This is a very interesting experiment involving a sanitation technology independant of water supply and offering the possibility of re-using well composted excreta as soil fertilizer. Photo 10 shows a tidy squatting plate and a bucket of water. The system is based on dry composting, and water is not supposed to be poured into the composting unit. Some of the units worked as double vaults. These were introduced because problems had been experienced with the 'multrum' (single vault with air-intake). The problems consisted in fly-breeding and the health risk from handling fresh excreta.

Pond systems are shown on photos 12, 13 and 14. Photo 12 shows a well-functioning pond with concrete slabs around the edge. No floating matter is seen on the pond, which is a good sign. By way of contrast photo 13 shows a pond which is overgrown. Floating weeds were allowed to grow because the pond surface was not kept free of floating matter. The rake on photo 8 should have been used for this purpose (at an early stage). Photo 14 shows ponds being completely bypassed. The nicely levelled ground now holds vegetable gardens and a soccer field, and only the inlet pipe discloses the actual purpose of the pond. The untreated sewage was dicharged directly to a stream.

Efficiency of Sanitation Planning

Often the visitor is left with the impression that the implementation of sanitation schemes had not been based on any planning at all.

One problem which is left unconsidered at some places is the control of sullage. Photos 15 and 16 show sullage being discharged to the surface drainage system. (Note the water supply pipes which are exposed to damage, corrosion and contamination.) Everything appears to work well until the main drainage canals are reached: photo 18. Here it appears that also toilets have discharged to the drains, and these actually open sewers constitute a latent health hazard. The main drain on photo 17 has a hole leading to a sewerage system. Only a few households ever connected and the system is therefore now partly used through connections to the main drains. One reason for the few connections was that no legislation existed enforcing households to connect.

At another place septic tanks were proposed for an urban area as part of a gradual introduction of a sewerage system. This is a very expensive way of upgrading sanitation systems, as investments in concrete tanks and soakaways will be lost when sewers are laid. Likewise the septic tank systems constitute a solution which is more expensive than a well-connected sewerage system for areas with a population density higher than e.g. 100 cap/ha.

Photo 18 shows an example of bad planning. A public toilet has been constructed - but, alas, lower than the main sewer pipe. The photo was taken with the photographer standing on top of the main sewer!

A common mistake is the introduction of a sanitation technology (e.g. sewerage) providing only one service level in a town showing great variations in income level, building standard and water supply level.

Design Criteria

Design criteria for the various technologies often originate from European standards. Thus a sewage treatment plant was designed to discharge an effluent conforming to the English 20/30 standard for rivers, despite the fact that completely different conditions prevailed here.

Design criteria and standards used in e.g. Europe can only be transferred to the developing countries, if they are adapted to each individual country. Thus effluent standard should be related to existing and future desirable quality of receiving waters.

Operation and Maintenance

Often operation and maintenance are not included in the planning of sanitation systems; moreover, this is a neglected field. A proper operation and maintenance of any system is of vital importance to the long-term functioning of the system. In future higher priority should be given to the expenses involved as well as to the training of personel. Likewise a proper organization should be responsible for operation and maintenance

Social Constraints

Apparently confusion prevails in appraising the investments to be made in the field of sanitation. Actually the sanitation technology provided was only at few places related to users' income level. Social surveys should form part of a sanitation planning to bring out the ability or willingness to pay for the system to be provided. Another reason why the sewerage system mentioned in connection with photo 17 had very few housholds connected was that the intended users could not or were not willing to pay the connection fee.

Social surveys are also important to ascertain preferences, habits and prejudices. At several places it was noted that very nicely built low-cost sanitation units were of no avail due to an 'unforeseen' unwillingness to use them.

In developing countries politicians are often faced with the task of making decisions on the sanitation technology to be implemented on a too slender background material. The basis of a sound decision is the availability of information on sanitation technologies, economy, socio-cultural conditions and environmental background. The 'best' solution might not be the right one.

Introduction of a new technology should also be followed up by education of the users. An example of an education poster is shown on figure 1.1.

It appeared that it was far less complicated to solve the sanitation problems applying to residents in rural areas and urban high-income areas than to solve the problems applying to urban low and medium income areas. Against this background it was decided to concentrate the contents of this report on complex urban areas.

Photos taken during visits to Kenya, Tanzania, Zambia, Ghana and Nigeria, 1975-1978.

Photo 1. Biofilter-plant. True copy of a system used in Europe. Filterbed and digesters.

Photo 2. Biofilter-plant. A new filter, identical to the existing one, under construction to the right, although the existing is mal-functioning.

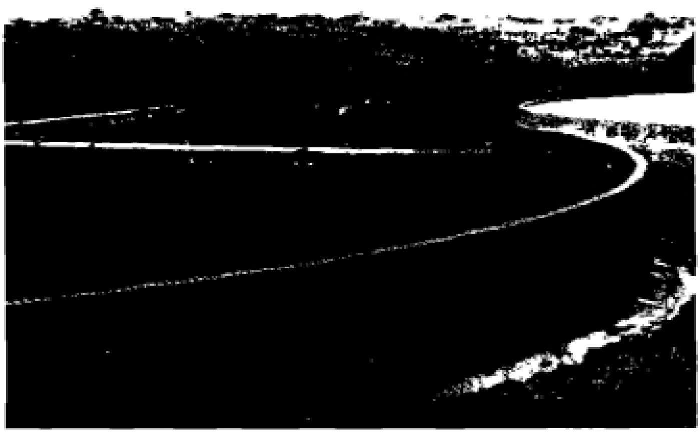


Photo 3. Ponds treating the bio-filter effluent.

Photo 4. Manually operated screen.

Photo 5. Mechanical screen.

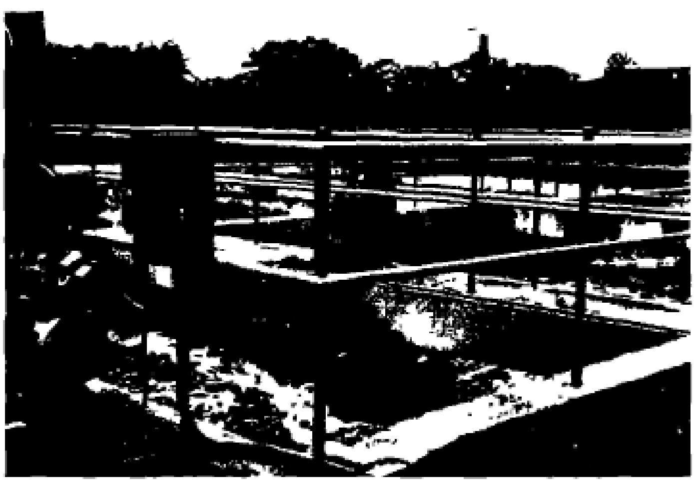


Photo 6. Surface aerator.

Photo 7. Jet-cleaner.

Photo 8. Rake made of sticks used for removing floating matter on a pond.

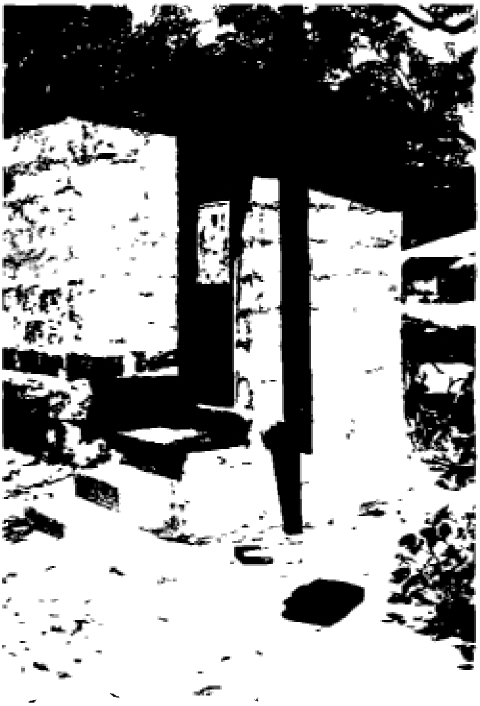


Photo 9. Compost toilet. Emptied at front.

Photo 10. Squatting plate with lid.

Photo 11. Compost toilet. Emptied at the back.

Photo 12. Well-functioning sewage treatment pond.

Photo 13. Owergrown pond.

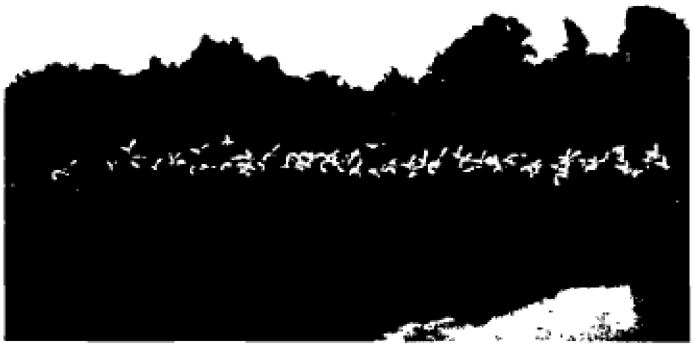


Photo 14. Inlet to bypassed pond. A vegetable garden is seen in front and a soccer field in the background.

Photo 15. Sullage discharge to surface drainage.

Photo 16. Surface drain and water supply pipe.

Photo 17. Fouled main surface-drain.
Connection to underground sewerage system to the right.

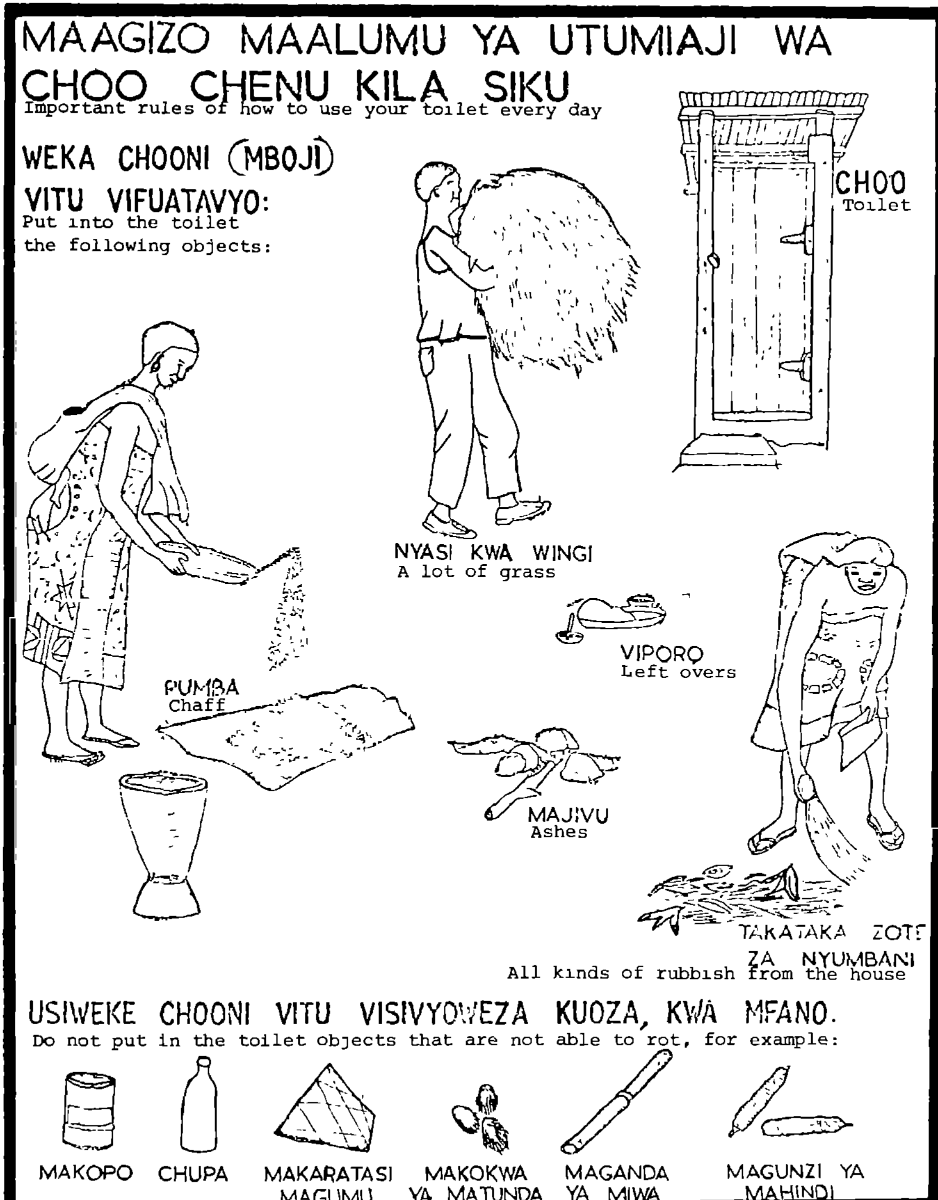
Photo 18. Public toilet located below the main sewer.

Photo 19. Children playing in lagoon fouled with hospital waste.

Photo 20. How do you solve their sanitation problem?

Fig. 1.1

Education poster for usage of compost latrine



Tins	Bottles	Hard paper	Peel from fruits	Sugar-cane bark	Maize cobs

2. PRIORITIES IN INFRASTRUCTURE

Distribution of Investments

General

The priority given the services in an infrastructure project vary greatly between and within the projects.

The World Bank indicates the following average distribution and ranges for sites and services projects all over the world /3/.

Cost item	Unweighted mean	Range
Land	21	14-28
Site preparation	13	0-19
On-site infrastructure	33	16-77
Plot development	33	4-62

Table 2.1 Major Cost Components in Sites and Services Projects (percentage of total site cost)

To illustrate how investments in infrastructure are distributed, a survey was made of the infrastructure projects that Cowiconsult, consulting engineers and planners, has prepared detailed design for. The results are shown in table 2.2. The table was prepared from detailed designs and tender documents using the contractors cost estimates. This means that the costs indicated for the projects are current market prices. The infrastructure projects in Tanzania and Kenya are typical upgrading projects or new developments at medium service level. The projects in Nigeria are either upgrading or new development projects at a high service level which the cost/ha also reveals.

Roads and stormwater

Roads and stormwatersystems are normally tied together and the cost distribution and cost/ha lie within the following ranges.

Cost distribution (12)	32%-75%	, average 60%
Cost/ha, US$	2,000 - 47,000 (254,000),	average 13,000

The cost distribution is fairly consistent around the 60% and the very low figures (12% and 32%) correspond with high investments in sewerage systems.

The cost/ha depends on whether the roads are surfaced or not and the stormwater ditches are lined or just earth drains.

Water Supply

The following ranges were found:

Cost distribution	5% - 46%	, average 24%
Cost/ha, US$	2,000 - 7,000 (16,000),	average 4,000

The very high percentages (34%, 42% and 46%) spent on water supply occurred where no sewerage systems were to be proposed. On the other hand fire hydrants were to be proposed in the same projects.

The cost/ha is very consistent which corresponds well with the fact that there are not many variations (or service levels) in house connected water supply.

Sewerage System

The following ranges were found:

Cost distribution	(0) 17% - 62%,	, average 34%
Cost/ha, US$	(0) 5,000 - 27,000 (58,000),	average 17,000

Three of the infrastructure projects had no proposed sanitation system at all.

Sewerage systems have not been provided at a wide range of service levels and the differences in cost/ha is more related to the population density. The cost distribution is very inconsistent and seems to depend on the quality of the proposed roads/stormwater or water supply system.

Conclusion of the Survey

The detailed survey of 10 infrastructure projects shows that there is a great variation in the priority given to the different services.

Depending on site conditions the services need to be weighted against each other. The attitude that sewerage systems are the only way of wastewater control for urban areas must be revised to prevent the wastewater control to be an issue of provision or no provision at all. Applying various on-site disposal systems would provide the desired financial flexibility to the solution of the sanitary problems of wastewater control.

Table 2.2 Infrastructure. Distribution of Investments. (Source: Cowiconsult AS)

Project Construct. year	Country	Subject	Area ha	Design Population Cap	Average Population Density Cap/ha	Total construction cost Project Time Local curr x 1000	Conversion to 1979	Total Cost 1979 Local curr. x 1000	Exchange rate 1979	Total Cost US$ x 1000	Cost/ha US$ x 1000	Distribution of cost	Remarks
Dodoma west 1979	Tanzania	Infrastructure	70	21,000	300	36,800		36,800	8.2	4,488	64	100%	Upgrading to high service level
		Storm Water	-	-	-	11,200		11,200	-	1,366	20	30%	Residential area
		Roads	-	-	-	15,300		15,300	-	1,866	27	42%	Trunk sewers not included
		Water	-	-	-	4,000		4,000	-	488	7	11%	
		Sewerage	-	-	-	6,300		6,300	-	768	11	17%	
Dodoma Chinangali 1979	Tanzania	Infrastructure	80	5,000	63	18,000		18,000	8 2	2,195	27	100%	Upgrading to medium service level
		Storm Water	-	-	-	3,700		3,700	-	451	6	21%	Residential area
		Roads	-	-	-	7,700		7,700	-	439	12	43%	Trunk sewers not included.
		Water	-	-	-	3,500		3,500	-	427	5	19%	
		Sewerage	-	-	-	3,100		3,100	-	378	5	17%	
Morogoro 1979	Tanzania	Sanitation	6,400	655,195	102	432,200		432,200	8.2	52,707	8		Upgrading and new development
		Sewerage	1,350	140,000	-	197,800		197,800	-	24,122	18		Residential and industrial ar.
		On-site disp	5,050	515,195	-	234,400		234,400	-	28,585	6		Treatment and trunk sewers included.
Mikocheni 1975	Tanzania	Infrastructure	35	10,200	291	4,337	1 6	6,939	8 2	846	24	100%	New Development to low service level
		Stormwater	-	-	-	117		187	-	23	1	3%	Residential area
		Roads	-	-	-	380		608	-	74	2	9%	Trunk sewer included
		Water	-	-	-	1,160		1,856	-	226	6	26%	
		Sewerage	-	-	-	2 680		4,288	-	523	15	62%	
Manzese B Tandale 1975	Tanzania	Infrastructure	210	32,000	152	5,000	1 6	8,000	8.2	976	5	100%	Upgrading to low service level
		Stormwater	-	-	-	1,600		2,560	-	312	1	32%	Residential area.
		Roads	-	-	-	1,100		1,760	-	215	1	22%	
		Water	-	-	-	2,300		3,680	-	449	2	46%	
		Sewerage	-	-	-	0		0	-	0	0	0%	
Manzese A Mburahati 1975	Tanzania	Infrastructure	320	48,000	150	7,600	1.6	12,160	8 2	1,483	5	100%	Upgrading to low service level.
		Stormwater	-	-	-	2,400		3,840	-	468	1	32%	Residential area
		Roads	-	-	-	2,600		4,160	-	507	2	34%	
		Water	-	-	-	2,600		4,160	-	507	2	34%	
		Sewerage	-	-	-	0		0	-	0	0	0%	
Sinza 1975	Tanzania	Infrastructure	234	45,000	192	7,100	1.6	11,360	8 2	1,385	6	100%	New development to low service level
		Stormwater	-	-	-	1,400		2,240	-	273	1	20%	Residential area
		Roads	-	-	-	2,700		4,320	-	527	2	38%	
		Water	-	-	-	3,000		4,800	-	585	3	42%	
		Sewerage	-	-	-	0		0	-	0	0	0%	
Molo 1979	Kenya	Infrastructure	4 3	3,480	145	1,340		1,340	7 4	182	43	100%	New development to medium service level.
		Roads	-	3,480	-	293		293	-	40	9	22%	Sewage treatment (septic-tanks) included
		Stormwater	-	3,480	-	131		131	-	18	4	10%	
		Water	-	3,480	-	139		139	-	19	4	10%	
		Severage	-	1,740	-	777		777	-	105	25	58%	

Table 2.2 Continued

Project Construct year	Country	Subject	Area ha	Design Population Cap	Average Population Density Cap/ha	Total construction cost Project Time Local curr x 1000	Conversion to 1979	Total Cost 1979 Local curr. x 1000	Exchange rate 1979	Total Cost US$ x 1000	Cost/ha US$ x 1000	Distribution of cost	Remarks
Asaba 1977	Nigeria	Sewerage	700	84,400	121	5,200	2.0	10,400	0 55	18,909	27		Upgrading to high service Level Residential and Industrial areas Treatment and trunk sewer included
		Stormwater	-	-	-	1,200		2,400	-	4,364	6		
Owerri 1979	Nigeria	Infrastructure	690	50,000	83	129,100		129,100	0 55	234,727	340	100%	New development to very High service level. Residential and industrial ar Sewage treatment and trunk sewer (10 times capacity) included.
		Roads	-	-	(For resi-	39,700		39,700	-	72,182	105	31%	
		Stormwater	-	-	dential &	56,400		56,400	-	102,545	149	44%	
		Sewerage	-	-	public ar.)	22,000		22,000	-	40,000	58	17%	
		Water	-	-		6,000		6,000	-	10,909	16	5%	
		Power	-	-	-	2,100		2,100	-	3,818	5	1%	
		Streetlight	-	-	-	2,700		2,700	-	4,909	7	2%	
		Refuse	-	-	-	0,200		200	-	364	(0,5)	(0,2%)	

Minimum Standard of Infrastructure

Setting a minimum standard of infrastructure is a political issue depending on social politics and economy. If no such policy or scheme exists, only urban rich people will be able to solve their infrastructure problems in an acceptable way.

Once a government defines the goals for a community, the desirable minimum health and living standards can be defined. Water supply, sanitation, roads and surface drainage must be provided at this minimum standard. The problem of building standard is not discussed here.

Here, the following minimum standards are suggested for an African urban community.

Water Supply

Water must be available within a maximum walking distance of 200 m from any plot. The supply system must prevent people from getting in direct contact with the source entailing the risk of contaminating the water. Water must be treated if the source is polluted or contaminated in order to remove any substance constituting a health risk to the population. A disease (like cholera) can easily be transmitted through the water supply if the pathogenes are not destroyed in a treatment process. The supply must also be sufficient in quantity, which means 20-40 litres/capita/day. Furthermore it must be reliable to prevent people from using unsafe water collected outside the supply system. Fire hydrants should be considered in high-density areas.

Sanitation

The sanitation system must prevent direct contact with fresh excreta. The handling of excreta must prevent the transmission of excreta-related diseases. This applies both when excreta are deposited on site or when conveyed to a central place for treatment. To make sure that people use the sanitation facilities, these must be convenient, easy to keep clean, easy to use, free from odour and insects and must secure privacy.

The ventilated improved pit latrine (see chapter 8, TYPE A) is rated as a minimum requirement for each household (or plot) if the ground conditions are fabourable for this technology. Aqua privies (see chapter 8, TYPE D) must be provided at locations with a high groundwater table or shallow rock. Only in exceptional cases are public toilets to be the only solution.

Roads and Surface Drainage

The access to plots must be dry all the year round, including bridges or transport facilities across waterways. Low class (Class C) roads should lead to or be within a 50 m reach of all plots. Likewise a reasonable access should be provided for emergency and refuse-collection vehicles.

The surface drainage system must be linked up with the road system. Unlined ditches must be constructed having a capacity sufficient to prevent flooding.

3. ABILITY TO PAY FOR SANITATION AND INVESTMENT SIZE

Introduction

Experience shows that a project stands a better chance of being realized if a community is financially self-reliant, in the sense that revenues collected on a project cover debt service, operation and maintenance. Also, the possibility of obtaining loans from international lending agencies is greatly improved if investments are related to the ability or willingness of the community to pay for the service provided. If this relationship is not considered, there is a risk that it is not possible to collect all the project costs among the users.

To reach an approach towards judgement of the financial resources which could be collected among the members of a community, an estimation is made of the proportion of the cash income that the households are able (or even willing) to spend on housing.

Housing

The term 'housing' has at least four different meanings:

- the house itself or the shelter
- the house including sanitation, where on-site disposal systems are constructed
- the house including on-site infrastructure
- the house including on-site and trunk infrastructure.

Generally housing is used in the broad sense of the word, e.g. by the World Bank /3/ and the Ministry of Land etc., Tanzania /2/, but often it is not clearly defined.

In the present paper housing is taken to include all infrastructure as defined by Marais /7/.

Income Groups

The income proportion which could be spent on housing by the households will depend on the their income levels.

The World Bank /3/ divides a community into four income groups:

- lower income group
- lower middle income group
- middle income group
- high income group.

Whether a household belongs to a lower or a high income group depends on the country to which it belongs. Thus a household from among the lower income group in a relatively high-income developing country could easily belong to the middle income group in a poor developing country.

Likewise the standard of housing which can be obtained for the same expenditure (e.g. expressed in US$) varies very much from country to country.

The cash income of a household usually consists of a formal income earned by the head of the household plus informal income earned by the other members of the household. The subletting of rooms also contributes to the cash income. Generally per capita incomes below $ 180 per year is rated as low income /6/.

Income Proportion Spent on Housing

According to the World Bank /3/ housing represents some 15-20% of household expenditure. A figure around 20% is supported by the National Housing Research, Nairobi /5/ and ODM, Ismalia /4/. The Ministry of Lands etc., Tanzania /2/, claims that residents in lower income areas are able and willing to pay up to 20% of the total household income for housing and those in a stronger income position up to 25%.

For planning purposes it is proposed that the income groups can spend the following proportions of their household income on housing:

- lower and lower middle income groups	15%
- middle income group	20%
- high income group	25%.

Proportion of Household Expenditure for Infrastructure

From out of the income proportion for housing, a certain percentage is available for the provision of infrastructure. Existing settlers are expected to be able to provide a larger proportion of the housing expenditure on infrastructure than are new settlers who have to give first priority to the construction of an acceptable 'shelter'. Still this difference can be neglected in cases in which a local lending institution provides low-interest loans for the construction of houses. Material loans are available at 5% from the Tanzania Housing Bank both for new settlers and for settlers in upgrading areas /2/. This loan possibility is expected to straighten out the main difference in 'shelter' expenses between existing and new settlers.

World Bank experience from sites-and-services projects shows a wide variation in the relationship between expenditure for plot development (core house and dwelling construction) and expenditure for on-site infrastructure, but on an average expenditures are equally distributed /3/. Thus expenditure on total infrastructure is more than 50% of total housing expenditure.

Detailed studies made by the Ministry of Lands etc., Tanzania /2/, and ODM, Ismalia /4/ indicate that expenditure on infrastructure ranges between 50 and 60% of housing expenditure.

In the present study an average figure of 55% has been adopted, which is on the lower side. Thus the proportion of household income spent on infrastructure is as follows:

- lower and lower middle income groups 15% x 55% = 8%
- middle income group 20% x 55% = 11%
- high income group 25% x 55% = 14%.

Theoretical Ability to Pay for Sanitation

Lower and lower middle income groups are assumed to be provided with at least pit latrines, public standpipes and low-class roads.

For the middle income group the minimum infrastructure service level provided will be: plot-connected water, power supply, better roads and sewerage or aqua privy connection.

The high income group is provided with house-connected water, power supply, paved roads and sewerage or septic tank connection.

The proportion spent on each infrastructure element will show great variation from project to project. From the infrastructure survey described in chapter 2 is derived that sanitation accounts for 1/3 to 1/4 of the total infrastructure expense. Thus the household income proportions which each income group can afford to spend on sanitation will be as follows:

- lower and lower middle income groups 2%
- middle income group 3%
- high income group 4%.

These percentages are somewhat low as compared to figures stated in World Bank papers /6/, but included in the above recommended figures is the assumption that users are expected to provide superstructures or house installation themselves.

Consequently households are assumed to be able to spend their incomes as shown on table 3.1.

Cost Recovery System

To express the household income proportions available for sanitation in potential investment capital, different ways of charging for sanitation systems will have to be looked upon:

1. A once-for-all fee based either on the cost of connection to a sewerage system or on the cost of providing on-site disposal system plus a monthly fee to cover operation and maintenance.

2. A surcharge per cubic metre used = the average incremental cost of sewerage x the proportion of water returned as wastewater. This system is usually only applied to sewerage systems, and the system is not applicable to on-site disposal systems like pit latrines.

3. A monthly flat fee including the annuitized portion of connection or provision cost, plus operation and maintenance cost.

Experience shows that connection to a sewerage system is more reluctantly accepted if a connection fee has to be paid. For low income groups it will take a long time to save enough money to pay the once-for-all fee for the provision of on-site disposal system.

The sanitary problems cannot be solved for urban areas in Africa without providing on-site disposal systems like pit latrines, and recovery system 2 cannot be used throughout.

The most attractive system is 3. The monthly flat fee could either be a repayment on a bank loan included in the land rent (plot rent), or it could be collected as a sanitation tax. The collection of an extra tax for sanitation opens the possibility of cross-subsidazion within a community and the enforcement of a sanitation programme.

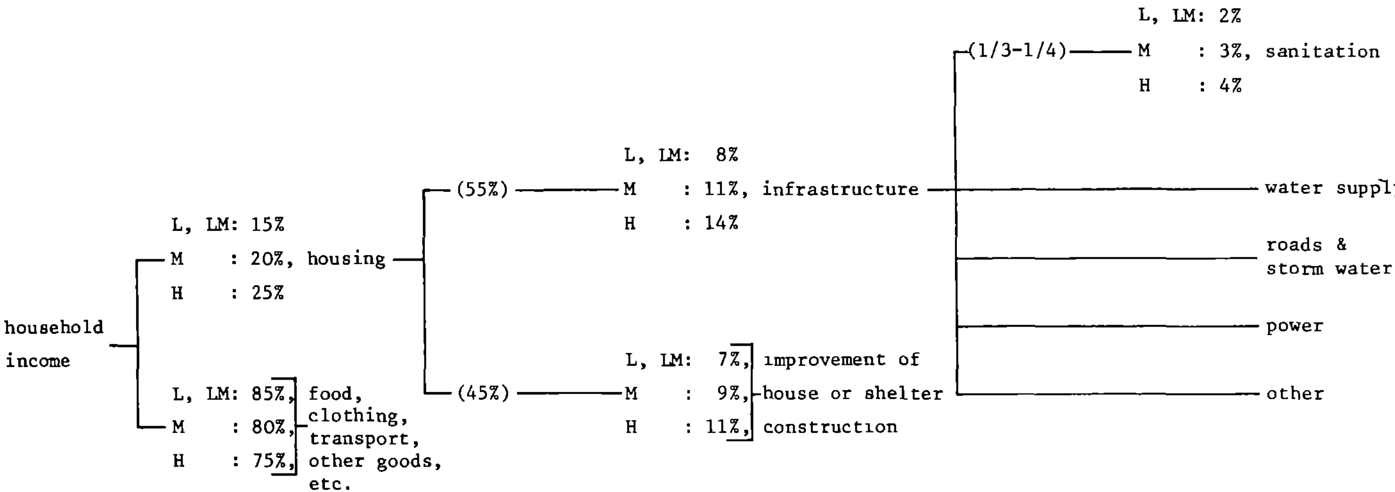
Investment Size

Assuming the adoption of the third cost system the monthly (or annual) fee will be equal to the household income proportion which each income group can afford for sanitation.

If sanitation systems are to be financed by individuals - through bank loans - the investment size for a household is attained by reserving a proportion of the fee for operation and maintenance and for the amortization of the rest.

If a sanitation programme is to be finanzed by an extra tax, this tax should have a size equal to the household income proportions spent on sanitation as indicated ppreviously. Such an extra tax to be paid by the households could be converted into potential investment capital by amortizing it as installments on a loan after the deduction of a portion for operation and maintenance.

Amortization generally takes place at interest rates ranging from 7% to 14%, with repayment periods of 15-25 years, according to the World Bank /3/. These ranges are supported by the Ministry of Lands etc, Tanzania /2/ and ODM, Ismalia /4/.



L = lower income group LM = lower middle income group M = middle income group H = high income group.

Table 3.1 Household Expenditure

4. APPROPRIATE SOLUTIONS IN INFRASTRUCTURE

General

Selecting appropriate solutions in infrastructure jobs is quite a complex task. Within each subject (roads, water supply, sanitation, stormwater) a wide range of alternatives exists, but the appropriate solution will often be the second best solution - since the perfect one seldom exists. The problem is rather to exclude certain technologies than to select the best one.

For each subject the technology known at present must be established. In the 1970s the eyes of many developing countries, banks, and aid organisations have been opened to the use of the so-called low-cost technologies for upgrading existing infrastructures, and planning new ones. Existing low-cost technologies have been recorded, and improvements suggested. Realising that conventional Western methods are beyond the reach of most developing country communities the transfer of low-cost technologies between the developing countries - and the improvement of these technologies - are now some of the main tasks for engineers engaged in developing countries' programmes and projects. This does not mean that only low-cost technologies are applied in developing countries, but these technologies are important when suggesting a solution catering for a whole community. The high-income areas will in general be served by conventional Western technologies.

In the following, some of the sanitation technologies are briefly described, including the infrastructural factors related to sanitation. (For more detailed description see ref. /6/ and /7/).

Furthermore, the criteria and conditions for selecting the appropriate solutions are discussed, with the concentration mainly on removal of excreta, sullage and refuse, as these are the most complicated problems to be solved in an infrastructure project.

Water Supply

Three levels of water supply are considered,

- public standpipes
- single-tap house connections
- multi-tap house connections.

Public Standpipes

The public standpipes can either be connected to a water supply system or be mounted directly on a handpump, or motorpump-operated well. The consumption is 20-40 litres/cap/day depending on walking distance to the standpipe and the supply capacity.

Single-tap House Connection

Each plot or house usually has a tap outside the house, and the water consumption is 40-80 litres/cap/day.

The problem of getting rid of the sullage is arising when such service level is introduced.

Multi-tap House Connection

The technology of water supply at this service level is of common Western standard, and the water consumption ranges from 100 - 200 litres/cap/day. This service level of water supply is required for introducing waterborne sewage, as will be discussed later in this report.

Water supply systems can easily be staged. In a low-income area public standpipes can be located to give a maximum walking distance of 200 m from any house. As the area is upgraded the supply system is branched out to each plot, and from then it is up to the plot owner to carry out multi-tap house connection. This staging is quite common, and it is therefore important to design water mains for the highest service level although a lower service level is introduced from the start.

Sanitation

Today a wide range of technologies is known for the removal of wastewater consisting of human excreta and sullage. The design and function of the various sanitation alternatives are described in detail in the literature, and in the discussion below the following basic sanitation alternatives are considered:

- Pit latrines
- Compost latrines, double vault latrines
- Bucket cartage
- Vacuum truck cartage (vault toilets)
- Aqua privies
- Septic tanks
- Sewerage

Other solutions are mostly variations of the above mentioned alternatives.

Pit latrines, compost latrines and bucket cartage, collect and remove only human excreta. Sullage must therefore be disposed of on the ground, tipped in gardens, or led to small soakaways or drains leading to street drains, depending on the quantities.

Sullage is not commonly led to the vault toilets either, but is often led to aqua privies and septic tanks. With regard to aqua privies and septic tanks sullage helps keeping the water-seal which is important to prevent insects breeding and the spreading of odour. If sullage is not led to any of these three tank alternatives it must be disposed of in a soakaway or led to the stormwater drains.

Sullage

When selecting sanitation technology it is important to consider the existing and anticipated water consumption. Is the water consumption relatively low, say 50 l/cap/day, the sullage can be disposed of on site of course depending on ground conditions and building density. Is the water consumption more than, say 100 l/cap/day some sort of sewerage system is required.

Stormwater

The quality of the stormwater drainage system generally follows the standard of the road system. The most simple system is drains cut in the ground. An improvement is lining the drains with stone pitching or concrete.

In a more advanced system the stormwater system will consist of closed gutters and culverts, which will be the system to be used when bitumen paved roads are introduced.

To reduce the size of the closed stormwater system a series of retention basins is constructed to even out the peak flows.

Refuse Collection

Refuse collection has typically a low priority in the developing countries. However, with the increasing population density the problem of indiscriminate refuse disposal becomes very serious.

Lack of proper refuse collection will harm stormwater and sewerage systems.

As a first attempt to organise refuse collection some countries e.g. Nigeria, have constructed 'refuse houses' near market places and other central places in towns. These - in fact shelters - have not been sucessful and cannot be recommended as a first-step refuse collection. A much better solution is the method of using large refuse containers (for instance 5 cu.m containers) placed strategically in a town, in market places as well as commercial and industrial areas. The walking distance should not exceed 150-200 m. The containers are frequently picked up by tractors or trucks and hauled to a dumping ground outside the town.

The highest level of service is the house-to-house collection system, where each house has its own 100 litre refuse bin. This system applies to low and medium density areas within the urban structure. Both existing high density areas (blocks of flats) and new areas need a refuse collection system using containers located inside - or next to the building (house).

Refuse bins - or containers - are generally emptied on a weekly basis. However, shortage of collecting vehicles, owing to break-downs, often prevents such frequent service.

Criteria and Conditions for Selecting Appropriate Sanitation Technology.

For the selection of an appropriate sanitation technology at a specific time for a specific part of a town, information on the environment, socio-culture and existing/proposed infrastructure is necessary.
The cost and management of the technologies must also be appraised. The combination of the above data will in general exclude most solutions leaving only a few possibilities to be implemented.

Environmental Conditions

Topography

The topography is important when looking for gravity solutions of both foul water drainage and rain water drainage. In flat areas deep excavations and pumping of sewage may be required, and thus will increase the cost and maintenance of a sewerage project considerably. Pumping may also be required in a hilly area where sewage is conveyed to a central place for treatment.

Ground conditions

The stability of the soil will influence e.g. the construction of pit latrines. In loose soils like sand, the pit will cave in if no side-support is constructed.

The permeability will influence the infiltration in pit latrines, the sullage and septic tank effluent's disposal into soakaways, and the runoff of rain water.

Rock close to the ground surface could hamper any excreta disposal considerably. Excavation will be costly, and this has in some cases led to the possibility of using the bucket/vault and cartage systems. To be able to use on-site excreta disposal, rock must be at least one metre below surface.

If the groundwater table is close to the surface this will reduce the possibility of infiltration and the use of soakaways. If the groundwater table is less than 0.5 m below ground level, infiltration is not possible, and on-site disposal systems cannot be used.

Removal of water from pipe trenches during the construction of sewers will increase the cost of the job considerably.

Climate

The frequency and intensity of storms are decisive of which measures are to be taken to protect against flooding - and the size of a requested stormwater system.

The air temperature influences the biological processes in aqua-privies, septic tanks and sewage treatment ponds. The higher the temperature, the faster the break-down of organic matter and destruction of pathogens.

Protection of the Environment

Water resources (also future) must be protected against pollution or contamination. For example could extensive soaking pollute the groundwater resources or discharge of untreated sewage could pollute rivers or streams.

Uncontrolled defaecating will create a serious health-risk and an unpleasant environment.

Socio-cultural Conditions

Population Density

If the population density reaches 200 cap/ha, or more, the on-site disposal systems become unfeasible, or even impossible, and sewerage or a cartage system are the only possibilities. Compost toilets are not recommended as there is obviously no use for compost within the high density areas. On the other hand, on-site disposal systems are very feasible in low density areas within the urban structure, depending however on the ground conditions.

As towns grow in size, they tend to become more complex and advanced technologies will thus be required.

Health

The only way to prepare a long-term prevention of excreta-related and water-related diseases is by introducing excreta and sullage removal and stormwater control. Most of the on-site disposal systems (except septic tanks) do not take care of the sullage, which becomes a serious problem - more or less serious, depending on the soil conditions and the population density. Standing pools of sullage or stormwater provide breeding conditions for pathogens carrying insects, and many pathogens such as helminthes, survive very well under wet conditions.

A well-functioning pit latrine gives the same health benefit against excreta-related diseases as a cistern/flush toilet system, but the problem of the sullage disposal makes the difference between the two systems.

Culture

The problem of the user's acceptance of a technology has often been neglected,even overlooked. The introduction into a society of a new sanitation system that may be against the user's religion or traditions will be almost impossible to establish.

Education and legislation could bring changes, depending however on the attitudes towards them in the society. If it is possible to improve the existing sanitation technologies this would in general offer the best low-cost solution.

Two examples of cultural influence on selecting sanitation technology should be mentioned. Contrary to the people of Asia, the people of Africa are strongly against handling of excreta - which in many cases eliminates the bucket/vault - cartage solutions, and to some extent the compost toilets. If it is practice in a society to use water for anal cleaning, compost toilets - which must be kept dry - cannot be suggested. On the other hand, this practice would secure the well-functioning of aqua-privies and water-seal toilets.

Socio-Economics

Depending on the policy of the country, the people will pay for the sanitation services themselves. If cross-subsidy through taxes - or other possible subsidies are left out the sanitation system is closely connected to the household income, and thus the housing standard. The total annual cost per household can be compared to the total annual household income, and assuming that people can use e.g. maximum 5% of their income on sanitation construction or improvements, pit latrines and bucket systems will be the only feasible solutions in squatter and low-cost areas. Another factor is that through education and/or legislation people could spend more on improving their sanitation conditions.

Cost and Management

Cost

The cost of the various sanitation technologies vary considerably from the low-cost pit latrine to the waterborne sewage system - a very important factor for finding the appropriate technology. As discussed above, the system will have to be selected to suit the financial possibilities of the user.

Furthermore, it is important to select the technology from the user's financial means, but also from the view point of the country's economy. The latter including all resources spent (including foreign exchange) and benefits obtained.

Another cost factor is the possibility of the user providing free labour in for instance a self-help scheme which would reduce his expenses and improve his motivation for using the technology.

Management

Some sanitation technologies imply much heavier demands on management and maintenance than other systems do. Pit latrines for instance do not imply heavy demands on institutional management - and in addition they are easy to keep clean and maintain. On the other hand, any cartage system will require a substantial management structure and regular maintenance. Cartage systems are very vulnerable to any break-down in for instance transport units. Sewerage systems also require management and maintenance, however, normally institutional, and seldom the user's responsibility

Conditions of Infrastructure

The sanitation technologies are interrelated with one or more of the other infrastructure factors, and these therefore are decisive for the possible solutions.

Water

The possible sanitation technologies that could be proposed for an area depend on the service level of water supply in that particular area. Cistern-flushed toilets can only be used if water is connected in the house. Aqua-privies can be used if plot connections are available, but are out of the question if the population has only access to public standpipes. This implies that improvement of sanitation technology is closely related to the service level of the water supply.

Also the quality and quantity of future water resources could reduce the per capita amount of water available if the resources are expensive to develop or even do not exist.

Stormwater and roads

Stormwater drainage is generally linked to the road system and is improved as the roads are upgraded. In few cases stormwater ditches are dug (or should be dug) outside roads, where flooding problems occur. Flood control is very important where pit latrines are used as these could overflow during a storm,creating health hazards.

Cartage systems and refuse collection are also depending on a road system. The roads must be of such a quality that refuse collecting and cartage vehicles can safely reach the bins and containers.

Building Standard

Generally the "shelter" or house is to be provided by the occupier of a site. The building standard will depend on his financial resources and his interest.

Sites and services schemes e.g. Dandora, Kenya /10/ do sometimes however provide core units (kitchen and bath) the remaining part of the house left to the occupier to built.

Improvement of building standard increases the possibility of extra income from subletting rooms. Also the location of a sanitation unit inside the house and multi-tap houseconnected water depends on the standard of the building.

Selection Procedure

When planning and designing a sanitation scheme some of the data are fixed, others variable. Physical data like ground condition and topography are typical fixed data that cannot be altered.

Economy, population density, service level, socio-economy and health are data that each can be given a high or low priority.

In the sanitation selection procedure there will thus be a number of fixed (cannot be given priority) data that will have to be considered first. This will serve as a "screen" leaving relative few possibilities that can be implemented. These possibilities must then be appraised against the variable data and selection is done by giving high priority to certain data.

5. PROJECT APPRAISAL

Introduction

An appraisal of alternative sanitation projects is done by technical, social, environmental, financial and economical appraisals. Within each area as many data as possible should be collected to allow for a realistic appraisal.

Technical Appraisal

The technical appraisal includes an evaluation of the data discussed in 'Criteria and Conditions for the Selection of Appropriate Sanitation Technology'. Also the use of mechanical equipment (pumping station, aerators, vacuum trucks, etc.) should be appraised.

Social Appraisal

The project should be appraised in relation to the users' preferences, habits and prejudices. This is far too often overlooked, the result being loss of investment.

It is of vital importance to have a throughout knowledge of the society where a scheme is to be implemented. It is to be assured that people will actually use the facility provided and it should be obvious attractive both financially and for the well-being to use it. It is strongly suggested to involve a local sociologist (where available) in the social appraisal.

Environmental Appraisal

Pollution of groundwater reserves and waterways can be attributed to soakaways and discharge of untreated wastewater to rivers etc. The consequences of any wastewater discharge should be appraised against the desired quality of the receiving waters (including groundwater). This is important both for the control of future fresh-water resources and the recreational value of lakes, rivers, seasides, etc.

The environmental effect of wastewater discharge may also be detrimental to or improve the health situation. If wastewater is treated effectively, pathogens are destroyed. In handling excreta the sanitary staff will be exposed to pathogenic contamination, and there is a risk of spillage.

Financial Appraisal

The prices used for the financial appraisal are market prices, i.e. the prices at which contractors tender for construction work and are paid for the work done. The methodology to be applied would comprise discounting of the cost value and the benefit streams at an appropriate discounting rate, which for developing countries typically falls within the range 7-14% (cf. 'INVESTMENT SIZE). It is not possible however to express the benefits from sanitation projects in monetary terms. Benefits must be expressed in no. of plots or persons connected to a sanitary unit or a sewerage system. In this report benefit is defined as a connection to a waste disposal system disregarding the quality of the system. Provided that the health benefit from the different systems are about the same (see p. 31) and that the water supply system is developed regarding the type of waste disposal system available to the user this is a reasonable approach.

If the type of waste disposal system were to be regarded in the benefit expression, the benefit could be the amount of wastewater that can be discharged.

Average Incremental Cost (AIC) - Approach

The problem of appraising benefits derived from sanitation systems is simplified by the average incremental cost (AIC) approach. The per plot AIC of a sanitation system is found by dividing the present value of the construction, operation and maintenance cost by the present value of the incremental plots connected. Thus this method takes into consideration that benefits received at a later stage are worth less than benefits received immediately. Here the AIC expresses the average annual cost of a sanitation system per plot connected.

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

where t = time, years

T = design lifetime, years (measured from start of project at $t=0$

C_t = construction costs incurred (market prices) in year t

o_t = incremental (from year t=0) operation and maintenance costs incurred (market prices) in year t

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

r = opportunity cost of capital (= discounting rates), percent times 10^{-2}.

Values of existing sanitary structures (constructed before year 0) and their running cost and benefits are not included.

Source: World Bank /6/.

By using the AIC approach it becomes possible to compare sanitation schemes based on on-site disposal systems with schemes based on conventional sewerage systems. One of the main differences between on-site systems and conventional sewerage systems is that on-site systems serve the design population immediately on completion, whereas the sewerage system will benefit few during the early years of construction, the design population being finally reached only over a long period.

The AIG approach is a way of expressing the efficiency of the investments made. When comparing two alternative projects based on the same size investment, the one with the lowest AIC has the most efficient utilization of investments if the quality of the benefit is disregarded.

The AIC approach can give an indication of the sanitation scheme having the highest connection rate assuming equal investments, but it does not reveal the number of plots connected in relation to the total number of plots.

However, this could be done by calculating the AIC as if investments are done so that all plots could be connected when established and inhabited. This procedure could be used as a basis for the evaluation of the AIC size for a given sanitation scheme.

The AIC at market prices is also an appropriate guideline for determining the sewerage charge, e.g. in case the sewerage charge is related to water consumption.

When appraising sanitation schemes for residential areas, it is important to calculate the AIC for industrial, commercial and public areas as well as for the total urban area. A sanitation scheme having a relatively low AIC for residential areas may have a relatively high AIC for the total urban area, such as it will appear from the case study described later in this paper.

The AIC approach can be used to decide when it will be feasible to start construction of a sewerage system. In towns in which very few households have house-connected water, only these will benefit from a sewerage system, which results in extremely high per plot AIC. This also applies to areas having a very slow development in housing standard and water supply and, consequently, in the possibility and desire of being connected to a sewerage system.

This will be illustrated by an example:

A town has 10,000 inhabitants on 1,000 plots. The price estimate used is as follows:

Construction

Trunk-sewer sewage treatment:	$ 500/plot
Sewer mains	$ 700/plot
Sewer laterals	$ 1100/plot
Plot installation	$ 700/plot

Maintenance

Trunk, treatment and mains	$ 10/year/plot
Complete system	$ 15/year/plot

Opportunity cost of capital	10%
Lifetime	40 years

Trunk sewer, treatment plant and sewer mains are constructed within the initial five years. Laterals and plot connections are installed concurrently with connections of plots.

The AIC per plot is calculated for three sequences of connection:

Sequence 1:

Period Years	Plots Connected %	Investments $	Maintenance $/year
0 - 5	0	1,200,000	10,000
5 - 10	20	360,000	11,000
10 - 20	100	1,440,000	15,000

AIC per plot = $792/year.

Sequence 2

Period Years	Plots Connected %	Investments $	Maintenance $/year
0 - 5	20	1,560,000	11,000
5 - 10	50	540,000	12,500
10 - 20	100	900,000	15,000

AIC per plot = $429/year

Sequence 3.

Period Years	Plots Connected %	Investments $	Maintenance $/year
0 - 5	50	2,100,000	12.500
5 - 10	80	540,000	14,000
10 - 20	100	360,000	15,000

AIC per plot = $330/year.

It is up to the politicians and economists to decide on the maximum AIC for a sewerage system, but according to the World Bank /8/ a maximum figure could be $400 According to the case illustrated above this means that 40-50% of the design population for a sewerage system should be connected within the initial 10 years to give a resonable annual cost per plot.

Cash-Flow Analysis

A cash-flow analysis of money flows at market prices indicates the annual financial requirement. Depending on the system of collecting installments, the analysis will show if subsidizing will be required.

Economic Appraisal

An economic appraisal differs fundamentally from a financial appraisal in that the prices used in the streams of investment, operation and maintenance costs are shadowed to ascertain the project cost in relation to the economy of the country.

The AIC approach is also used for economic appraisal, where it gives the cost from an economic efficiency standpoint. The shadow factors used to attain shadowed cost are here experience values taken from the World Bank /9/ and ODM /4/. The shadow price expresses the social value of a good.

The shadowed costs are influenced by the availability of: unskilled labour foreign exchange, local and imported materials.

If the stream of benefits are expressed in e.g. plots connected in the AIC calculations, only the benefits can not be shadowed.

The discount rate used for economic appraisal is here assumed to be the same as that used for the financial appraisal.

6. CASE STUDY, GENERAL

Introduction

To illustrate the problems and consequences of investment in different types of sanitation systems a case study has been made of three alternative sanitation programmes. The provincial capital Morogoro in Tanzania was selected because:

- it represents a major urban area with development problems typical for Africa
- comprehensive material is available for this town.

Each of the three alternative sanitation programmes is based on annually available funds attained in accordance with the principles set out in chapter 3: 'ABILITY TO PAY FOR SANITATION AND INVESTMENT SIZE'. A 30-year planning period is divided into three phases· phase 1 (1979-1984), phase 2 (1984-1989) and phase 3 (1989-2009).

General Background

Fig. 6.1 shows a map of the present Morogoro, which has a population of 80,000. It is situated 200 km to the west of Dar es Salaam. Both the Central Railway Line and the Tanzanian Highway are passing through the town. They are of great importance to the future growth and development of the town.

The township area comprises 6,400 ha. The extension of the present town and planned sites-and-services projects are indicated on the map /1/.

A description will be given of the environmental and socio-cultural conditions and of the status of the existing infrastructure in Morogoro in order to illustrate the background for the sanitation systems selected and their phased developments.

Environmental Conditions

Topography (fig. 6.2)

Morogoro is situated at the foot of a mountain range to the south, from where the township area extends through the gently northerly sloping ground. The general direction of natural drainage is therefore south-north.

The township area is divided into five main catchment areas:

- Catchment area A to the north contains at present a low-income settlement. This area drains towards the Ngerengere River.
- Catchment area B comprises the main part of the existing town including commercial, industrial and public areas. This area drains towards the Morogoro River.
- Catchment area C is largely designated for farming, and no town development takes place here.
- Catchment areas D and E to the east comprise no town developments at the present time, but will in future have residential settlements.

From catchment areas A and D sewage can drain by gravity through long trunk sewers to the same point as the trunk sewer from catchment area B /1/.

Ground Conditions (fig. 6.3)

Hard and solid rock formations form the bedrock under the town, which can be located at a relatively shallow depth (1-3 m). Consequently the bedrock is of great importance to sanitation systems, as any deep excavation will increase construction cost considerably.

The shallow bedrock also results in a high groundwater table, which will impair the proper function of on-site disposal systems (soak-aways) and increase the cost of sewer construction. To the north there are swampy areas around the Morogoro River.

Groundwater is not used for domestic purposes. Groundwater pollution from on-site disposal systems will not be serious until it comes to have a detrimental effect on the rivers.

Fig. 6.3 shows the areas having the worst ground conditions. As the groundwater table varies seasonally, indications are given for the wet season /1/.

The character of the soil varies from gravel and sand to silt and clay. This means that pits will have to be reinforced in places where the soil is unstable, e.g. gravel with a small clay content.

Socio-cultural Conditions

Population Density (Fig. 6.4, 12.1, 12.2 and 12.3).

At the present time high population density areas (> 100 cap/ha) are situated in the areas with bad ground conditions (fig. 6.3) and malfunctioning pit latrines (fig. 6.6). These areas constitute typical 'immediate-action' areas for the solution of sanitation problems.

Areas around the existing commercial centre in area 21 will in future have densities below 100 cap/ha, whereas the rest of the town will develop towards densities between 100 and 200 cap/ha.

Population Growth

According to the sanitation project worked out by Cowiconsult /1/ a population projection was agreed with the Urban Planning Division of Morogoro. A very high growth rate of 8.5% per annum was adopted for the period 1979-1994 due to the planned expansion of industries. For the period 1994-2009 a growth rate of 6% per annum was adopted. As the case study mainly deals with residential areas, the total population in such areas has been calculated.

YEAR	GROWTH RATE	TOTAL RESIDENTS	RESIDENTS IN RESIDENTIAL AREAS
1978		74,115	70,747
	8.5%		
1979		80,415	76,760
	8.5%		
1984		120,916	116,221
	8.5%		
1989		181,816	176,076
	8.5%		
1994		273,390	262,774
	6.0%		
2009		655,195	648,430

Table 6.1 Population Projections.

Land Occupancy

Surveys conducted by the Ardhi Urban Planning Division covering several Tanzania towns /2/ show an average of 8 people per plot and 2 households per plot. Still, a shortage of accomodations is to be expected owing to the high influx of people to Morogoro stimulated by the industrial programmes. A figure of 9 people per plot is therefore adopted, and the average of 2 households per plot is maintained

From table 6.1 the number of plots in residential areas can be derived by using the figure of 9 residents per plot.

PLANNING PERIOD	YEAR	RESIDENTIAL PLOTS
	1978	7,861
PHASE 1	1979	8,529
	1984	12,912
PHASE 2	1989	19,564
PHASE 3	1994	29,197
	2009	72,048

Table 6.2 Number of Plots in Residential Areas.

Household Income Distribution

Information on household income distribution for Morogoro has been taken from the report: "National Sites and Services Project Phase III, Morogoro", January 1979 /2/. At 1979 prices the population has been estimated to conform to the household income distribution shown in table 6.3.

	PERCENTAGE OF HOUSEHOLDS	HOUSEHOLD MONTHLY INCOME	
		RANGE	MID. POINT
GROUP I	0 - 25%	up to 540 Tsh	450 Tsh
GROUP II	26 - 50%	541 - 860 Tsh	660 Tsh
GROUP III	51 - 75%	861 - 1400 Tsh	1120 Tsh
GROUP IV	76 - 100%	1401 plus Tsh	2100 Tsh

Table 6.3 Household Income Distribution.

These estimates are based on housing and household surveys made by Bureau of Statistics and on "Tanzania Basic Economic Report", December 1977, issued by the World Bank.

The household income for each income group consists of a formal wage which is increased by 20% to include informal income. The household income is related to the main wage earner income, assuming that for each household the main wage earner provides the bulk of the household income except for the highest income levels.

The household surveys in Morogoro shows that the better the houses are, the more common is secondary income from subletting rooms.

Household incomes have been assumed to remain constant, in real terms, over the planning period. This means that incomes are expected to rise at the same rates as the inflation. A case could be made for increasing real income to reflect national GNP/capita growth rate (+1.7 for Tanzania), but this would require the assumption that these incomes are being enjoyed throughout all the range of incomes, and particularly that the low income group is receiving its share. There are far too little data to accept this assumption, and it is felt that the safest position, especially for analyses of ability to pay for housing, is one of constant real income.

Figures 6.5, 12.4, 12.5 and 12.6 show the distribution of the four income groups on residential areas. This distribution is based on the land use observations made by Cowiconsult /1/. The housing standard, which includes water supply level and the level of sanitation systems, has been the main factor in determining the distribution for 1979. The future distribution of income groups is based on information on sites and services projects, where available /1/ and /2/.

Health

The current health situation in Morogoro has recently been surveyed by the World Bank /1/. Beside outbreaks of the typical excreta-related diseases typhoid and cholera, other diseases related to wastewater management were reported, such as viral and bacterial diarrhoeal diseases, intestinal worms (Ascaris), shistosomiasis (urinary) and malaria.

According to available records (1976-1978) 50% of the out-patient visits were water and/or excreta related. Thus there is no doubt that there is a need for a fast solution to the sanitary problems.

Culture

The sanitary surveys conducted July 1979 by the Tanzanian Ministry of Lands, Housing and Urban Development established the fact that water is being used for anal cleansing by virtually everybody /1/. This information was decisive for proposing the pour-flush bowl in alternative 2.

The survey also showed that there is a strong wish to have sanitation facilities improved and a willingness to make a financial contribution to this purpose.

Conditions of Existing Infrastructure

Wastewater Disposal Facilities (fig. 6.6)

At present there is no sewerage system in Morogoro. The majority of the population use pit latrines, whereas the rest of the population avail themselves of septic tank/soakaway systems. On-site disposal systems are functioning well in places where ground conditions are favourable (cf. fig. 6.3) and constructions have been properly done. Still most of the pit latrines are malfunctioning as indicated in fig. 6.6 owing to bad ground conditions and inappropriate con structions. This information is important when considering the quantity of existing facilities which have to be renewed in an 'immediate-action' sanitary programme.

At present there is a system of emptying flooded pits by vacuum trucks, which means that there is a sludge collection system which could be further developed.

Public toilets are located at market places, bus stations and in similar places. In several of these toilets there are problems due to improper use and lack of maintenance. Experience clearly shows that public toilets will not be the solution to sanitary problems in residential areas. The sanitary survey described by Cowiconsult established the fact that the large majority of the population would prefer using a neighbour's facility instead of a (clean) public toilet, in case the pit of their own was flooded.

Water Supply System (fig. 6.7)

The existing water supply system of Morogoro derives water from the Morogoro River upstream the town. Most of the present town is being reached by the water mains. Water supply authority records /1/ show that the service level in Morogoro is as follows:

- House connections — 20% of the population.
- Plot connections — 40% of the population.
- Communal standpipes — 40% of the population.

At present the capacity of the distribution system is inadequate, and it is proposed to construct new mains and water intakes.

Residential Building Standard

According to a survey conducted in 1974, /1/, 37% of the houses were of good durable construction, 24% of were fair, and 39% were of poor standard and built of temporary materials.

Many new houses have been built, but the number of squatter houses has also increased, so the above proportions are probably quite representative.

Investments in Sanitary Systems

Annually Affordable Instalments

The income proportions proposed in chapter 3 'ABILITY TO PAY FOR SANITATION AND INVESTMENT SIZE' and the information given under 'Household Income Distribution' and 'Land Occupancy' for Morogoro are used to derive the annually affordable installments for sanitation per plot for each income group.

Group I:	2% of 450 x 2 x 12 =	216 Tsh/year/plot
Group II:	2% of 660 x 2 x 12 =	317 Tsh/year/plot
Group III:	3% of 1120 x 2 x 12 =	806 Tsh/year/plot
Group IV:	4% of 2100 x 2 x 12 =	2016 Tsh/year/plot

Table 6.4 Annually Affordable Instalments.

Thus the average annually affordable instalment is Tsh 839/plot.

Cost Recovery System

In the case of Morogoro it is assumed that sanitation installments are to be collected through the municipality tax system. This cost recovery system offers the opportunity

- to collect from people not being connected or provided for, but benefitting from the general environmental improvement
- to collect from people disregarding which type of sanitation system is provided
- to collect from people before they are actually connected
- to cross-subsidize between the income groups
- to induce 'willingness' to pay if sanitation systems are legally required.

Investment Size

The maximum annually affordable installment for each phase is calculated in the following table using the information from tables 6.2, 6.3 and 6.4.

	INCOME GROUP	NO. OF CAPITA	NO. OF PLOTS	ANNUAL INSTALLMENT	ANNUAL INSTALLMENT MILL. Tsh
	I	29,055	3,228	216	0.70
PHASE I	II	29,055	3,228	317	1.02
1979-1984	III	29,055	3,228	806	2.60
	IV	29,056	3,228	2,016	6.51
TOTAL		166,271	12,912		10.83
	I	44,019	4,891	216	1.06
PHASE 2	II	44,019	4,891	317	1.55
1984-1989	III	44,019	4,891	806	3.94
	IV	44,019	4,891	2,016	9.86
TOTAL		176,076	19,564		16.41
	I	162,108	18,012	216	3.89
PHASE 3	II	162,107	18,012	317	5.71
1989-2009	III	162,108	18,012	806	14.52
	IV	162,107	18,012	2,016	36.31
TOTAL		648,430	72,048		60.43

Table 6.5 Maximum Annual Instalments.

We find it very optimistic that it should be possible to collect the extra tax from people right from the start of a sanitation programme. To take this into account we assume that only 50% can be collected in phase 1, but after 1984 everybody will pay this extra tax. Thus the annually available installments will be·

1984:	10.83 : 2 =	Tsh 5.42 mill.
1989:		Tsh 16.41 mill.
2009:		Tsh 60.43 mill.

The annually available installments for phase 2 is the difference between the annually available installments in 1989 and the annually available installments used in phase 1.

At the end of phase 3 the first 20-year period will have expired for those settling before 1989, and the investments made in phases 1 and 2 will be paid back. Thus the people having settled before 1989 can contribute to investments in phase 3.

Thus the annually available installment for each phase is as follows:

Phase 1:		Tsh 5.42 mill/year
Phase 2:	16.41 - 5.42 =	Tsh 10.99 mill/year
Phase 3:		Tsh 60.43 mill/year.

The capital investment for any phase in a given sanitation alternative is derived by deducting the annual operation and maintenance cost for the phase from the annually available installment and amortize this at 10% over 20 years. Amortization at 10% was recommended in the 'National Sites and Services Project, Morogoro /2/. A period of 20 years may seem to be a long period for pit latrines having a lifetime of 5-10 years. In the case considered it is, however, assumed that pit latrines are used over a longer period owing to an organized system of emptying the pits.

FIG 6 1
MOROGORO TOWN 1979

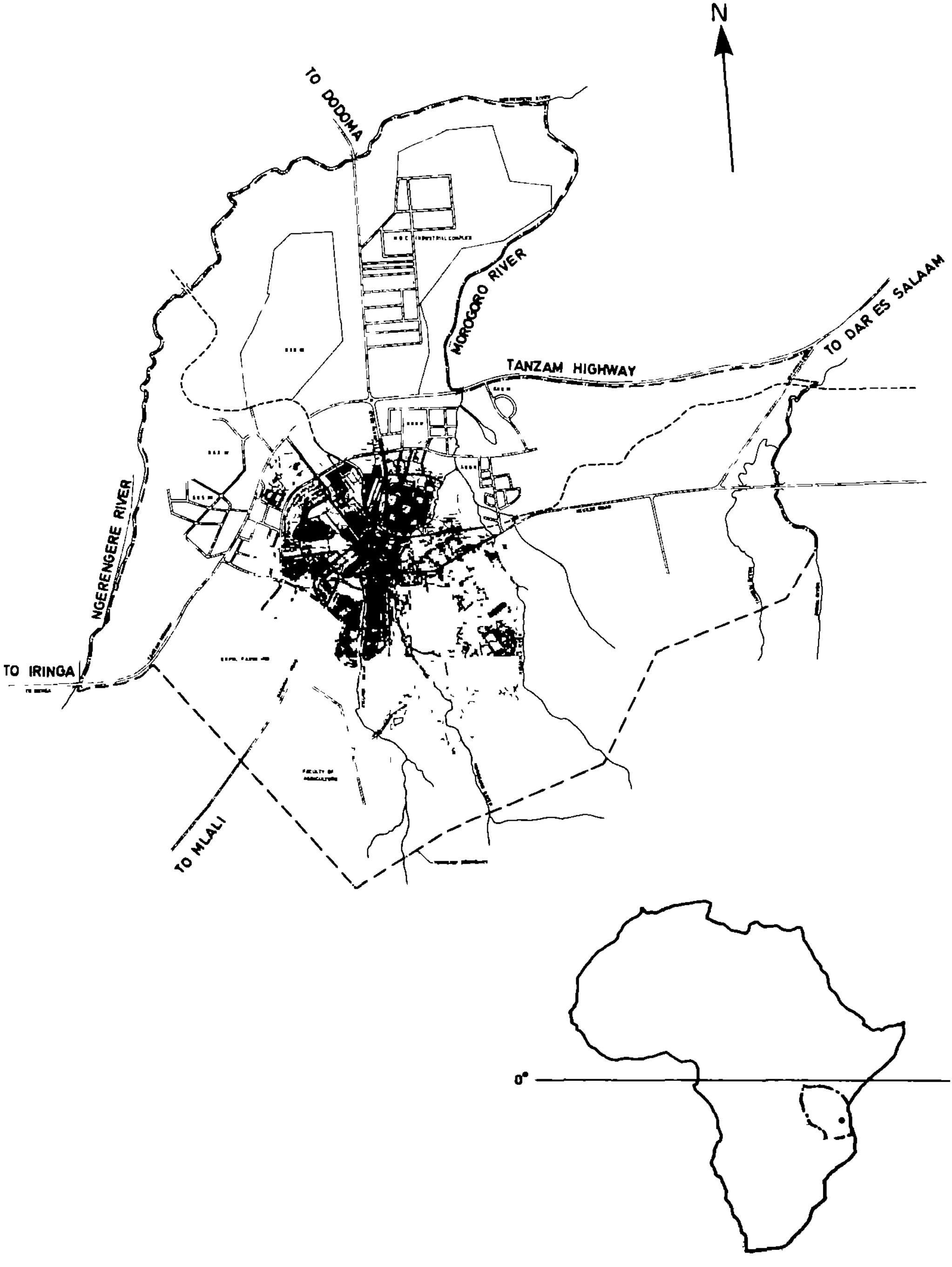


FIG 6.2
TOPOGRAPHY
CATCHMENT AREAS

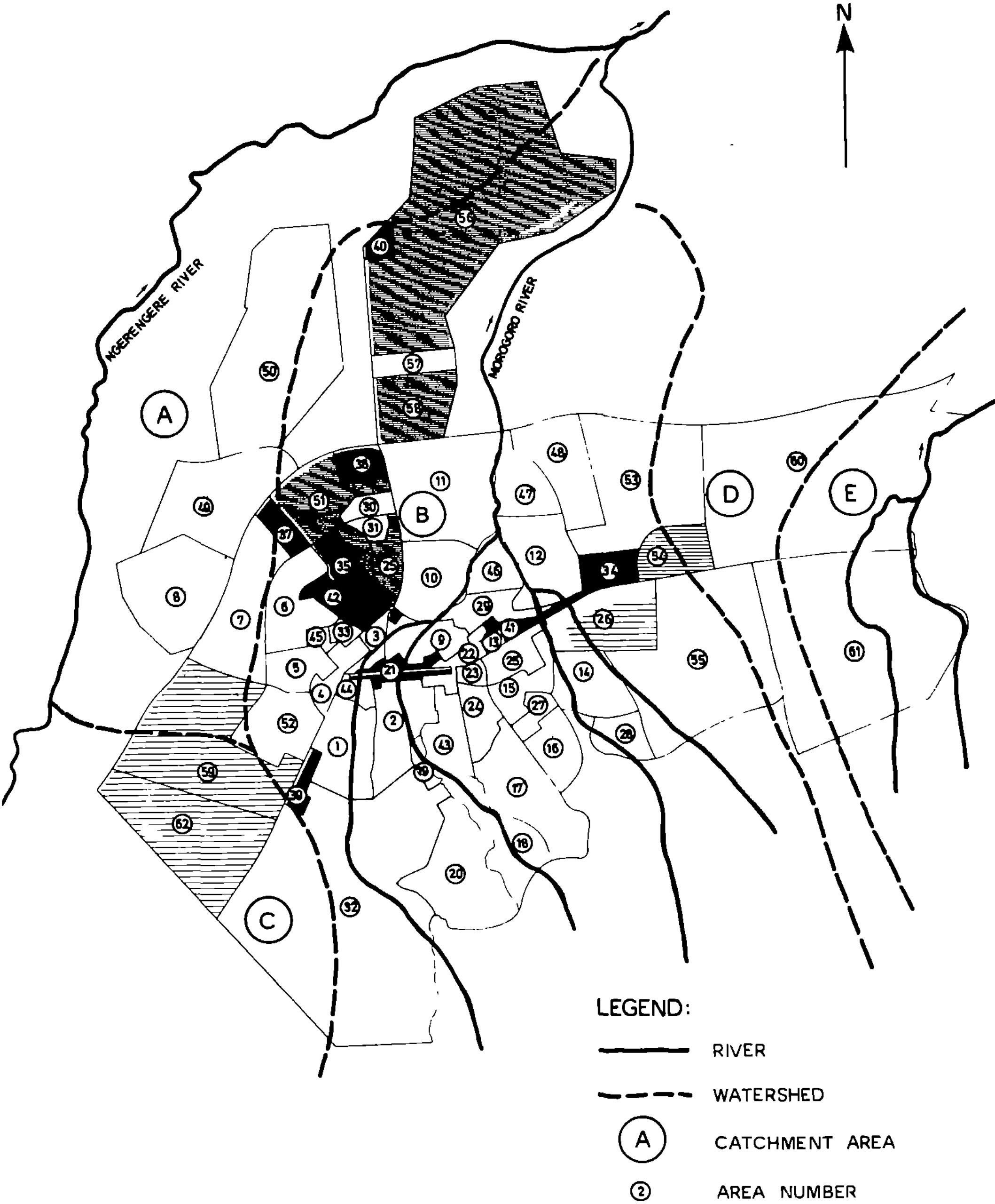
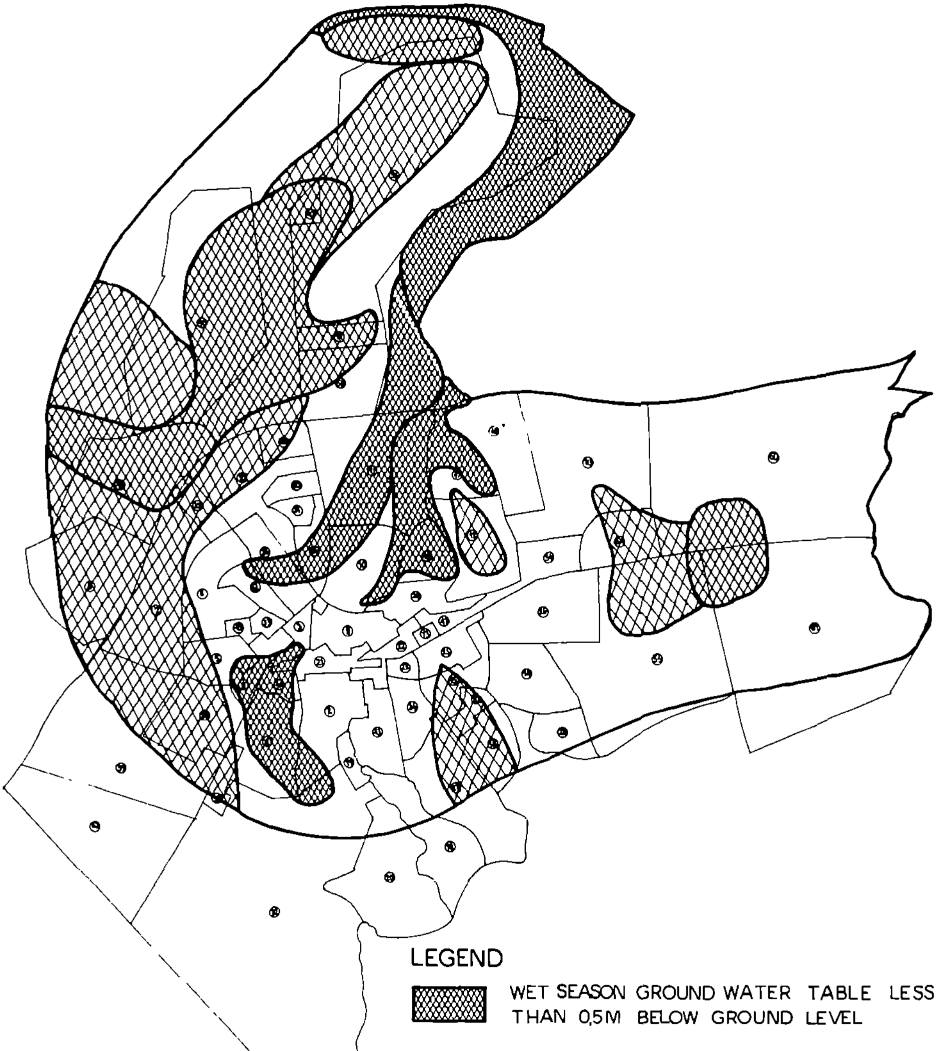


FIG 63
PRESENT GROUND CONDITIONS



LEGEND

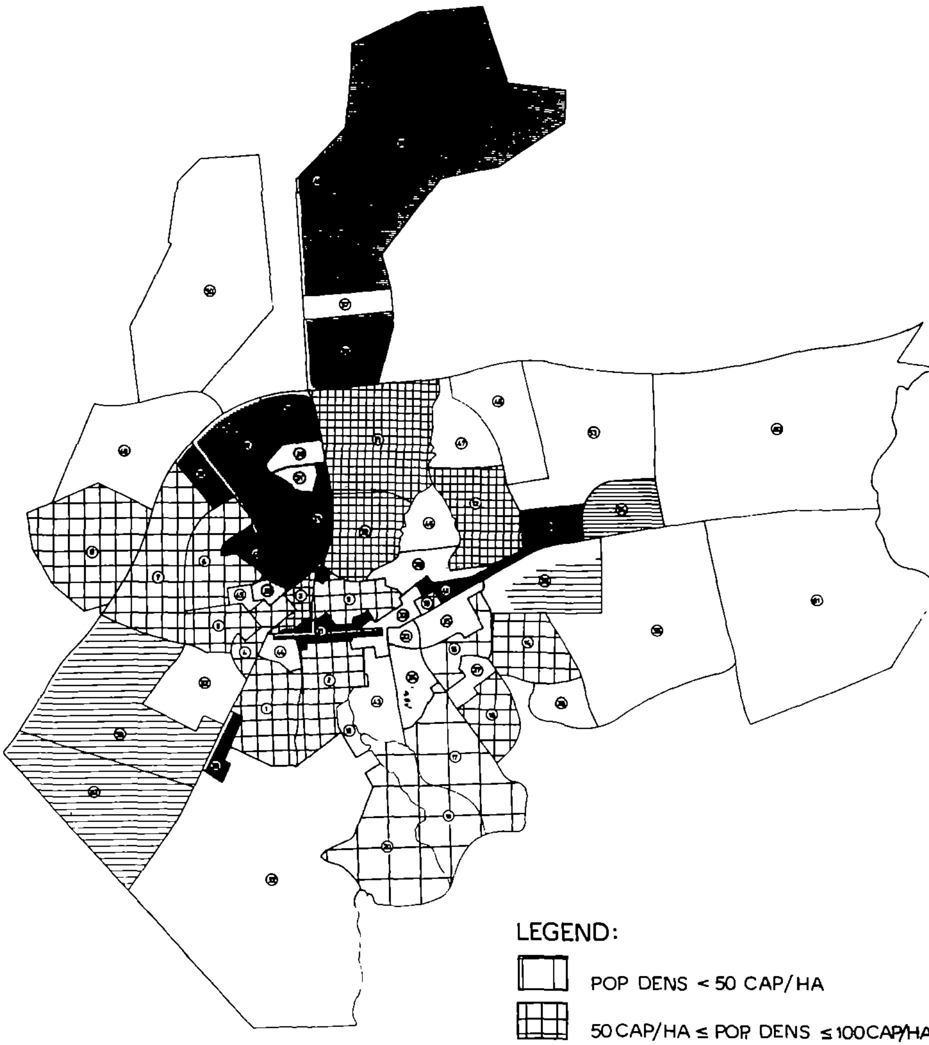
WET SEASON GROUND WATER TABLE LESS THAN 0,5M BELOW GROUND LEVEL

ROCK LESS THAN 1,0M BELOW GROUND LEVEL

ROCK LESS THAN 1,8M BELOW GROUND LEVEL

WET SEASON GROUND WATER MORE THAN 05M BELOW GROUND LEVEL AND ROCK MORE THAN 1,8M BELOW GROUND LEVEL

FIG 64
POPULATION DENSITIES 1979
(RESIDENTIAL AREAS ONLY)



LEGEND:

POP DENS < 50 CAP/HA

50 CAP/HA ≤ POP DENS ≤ 100 CAP/HA

POP DENS > 100 CAP/HA

ALL OTHER SIGNS INDICATE INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS

FIG. 65

INCOME DISTRIBUTION 1979

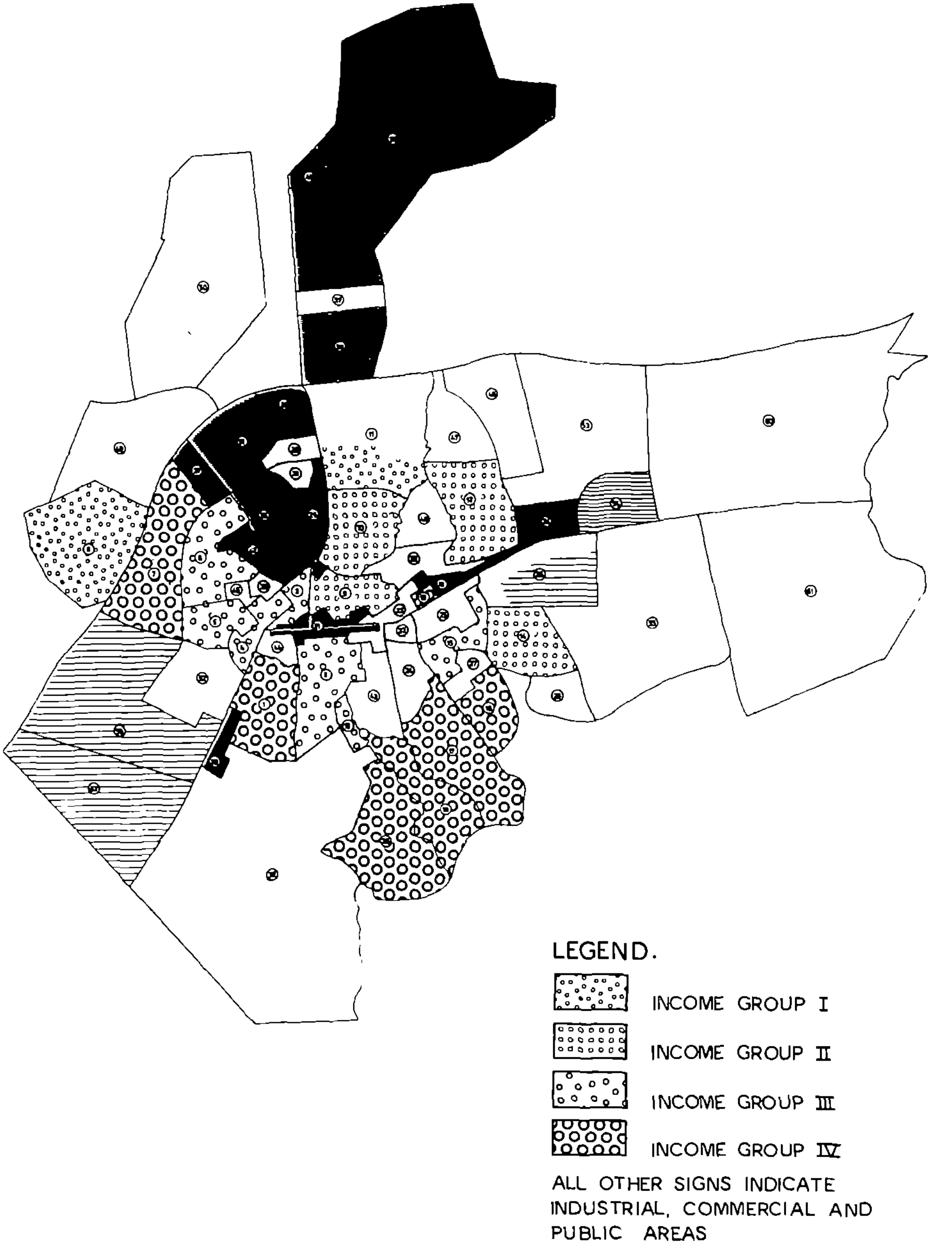
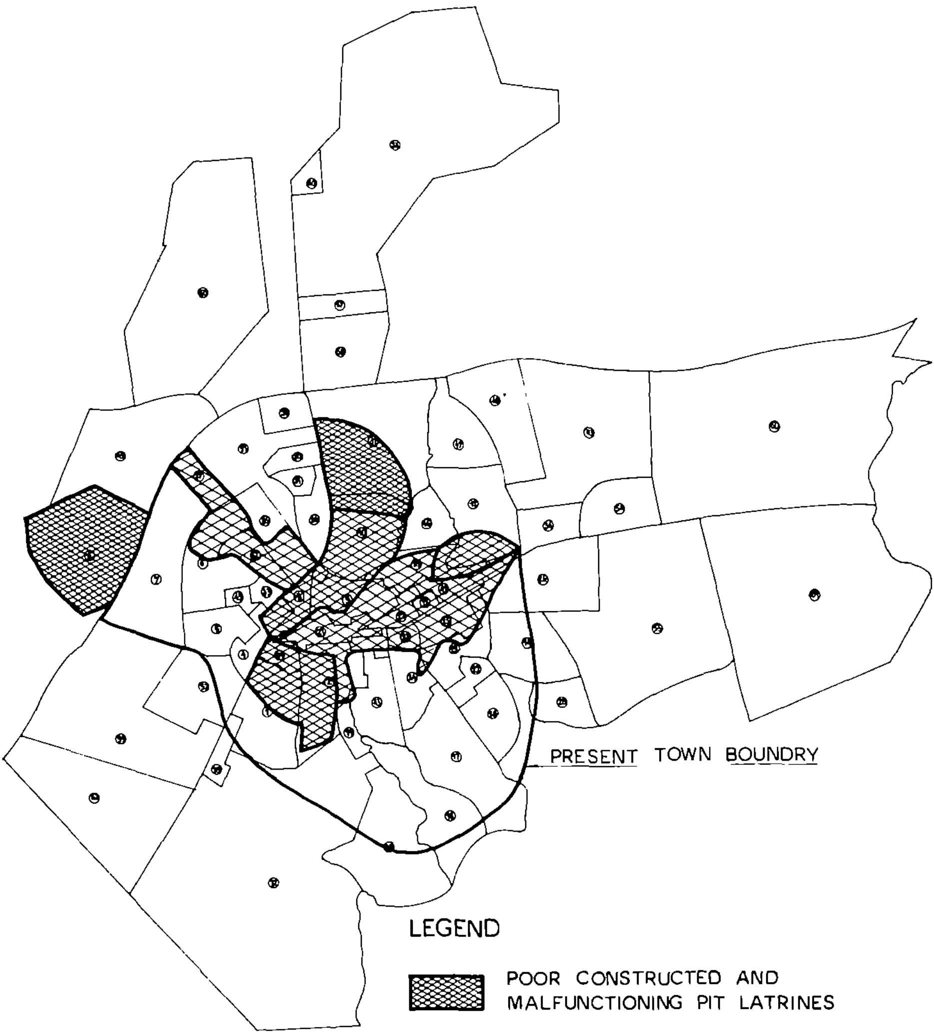


FIG 6.6

CONDITION OF EXISTING FACILITIES

(100% ON-SITE DISPOSAL SYSTEMS)



LEGEND

- POOR CONSTRUCTED AND MALFUNCTIONING PIT LATRINES
- UNSATISFACTORILY FUNCTIONING PIT LATRINES
- SEPTIC TANKS AND SOME PIT LATRINES NOT WELL FUNCTIONING
- SEPTIC TANKS AND PIT LATRINES WELL FUNCTIONING

FIG 6 7
EXISTING WATER DISTRIBUTION SYSTEM

7. ALTERNATIVE 1

Sewerage System

The procedure mostly adopted when solving sanitation problems for urban areas in the developing world is to introduce the sewerage system. Generally town centres with commercial areas are the first part sewered; gradually residential, public and industrial areas are connected to the system. This implies that the trunk system must be carefully designed to allow for the accomodation of possible (planned) future connections. This means that investment per plot will be relatively high in the first phase of the construction period, after which the investment will decrease as more and more plots come to share the burden of the trunk system.

The sewage treatment system has, however, an adverse effect on this. As long as the population is below e.g. half a million, the stabilization pond system provides a safe and cheap treatment procedure at a reasonably sized area. When the population increases towards one million, however, land requirement becomes excessive and the need arises to apply more advanced (mechanical) methods, resulting in a considerable increase of the cost incurred by the treatment system.

In this alternative all investments are concentrated on a sewerage system. Yet existing and future privately constructed on-site disposal systems are assumed to be maintained (emptied) by the public sanitation maintenance organization. Thus everybody is benefitting to some extent in this sanitation alternative, even though many are not provided with a sewerage connection.

The sewerage systems follow the alignments and dimensions as set out in the preliminray design report by Cowiconsult /1/. This report also forms the basis of the connection rates and cost estimates applied.

The central part of the town including the commercial centre is sewered first. Fig. 6.2 indicates the five catchment areas of the town. Only by pumping can these areas be connected to the same trunk system. The present population density, building standard (house-connected water) and location of commercial and industrial areas clearly justify an initial construction of the sewerage system in catchment area B. During phase 2 this central sewerage system is expanded as the population increases and more funds become available. Phase 3 includes the construction of sewerage systems in catchment area A, D and E.

In Chapter 6 it is mentioned that 20% of the households have water connected and that 40% have a plot standpipe. Thus water-borne sewage can not be ruled inappropriate considering the service level of water supply.

Cost Estimates

The cost estimates include: sewage treatment, trunk and main system, laterals and plot connections, but not the house installation. A plot connection is assumed to cost Tsh 3,500 per plot. With the addition of 20% contingencies the cost will be Tsh 4,200. Other rates used for the preparation of the cost estimates are shown in the appendix E describing the background for the selected rates.

Phasing of the Sewerage System:

Phase 1: 1979 - 1984

As described earlier catchment area B including the commercial centre of the existing town, is sewered first. In addition to the connection of high-density residential areas, industrial and public areas are expected to be connected. The industrial area comprises a slaughter house, an oil mill, a tannery and a textile mill, all of which would need a sewerage connection to protect the environment. In the public areas, schools and a hospital are expected to be connected. Estimates of discharges from residential, commercial, public and industrial areas as calculated in the preliminary design report by Cowiconsult/1/ show that discharge from the residential areas account for 70%. To attain the cost estimates for the residential areas, 70% of the cost for sewage treatment, trunk sewer and main sewer will therefore have to be attributed to the residential areas. Sludge collected from septic tanks and wet pits is disposed of in the sewage treatment ponds.

Operation and Maintenance:

It is estimated that two vacuum trucks will be required during the first phase to empty existing and new privately constructed pits and tanks. One of the vacuum trucks is a combined vacuum truck and jet cleaner, as this allows for the vehicle to be applied for maintenance of the new sewerage system as well.

One labour team runs the sewage treatment ponds, and the sewer cleaning is run by another team.

Total operation and maintenance cost: Tsh 950,000/year.

Investment.

Available in 1984: Tsh 5.42 mill/year.

Investment size for phase 1: (5.42 - 0.95) x 8.5136 x) = Tsh 38.0 mill.

Table 7.1 shows the number of plots connected in each area, and fig. 7.2 shows the system to be be constructed in phase 1.

The investment is utilized as follows:

Sewage treatment ponds and trunk sewers	Tsh 9.6 mill.
Main sewers	Tsh 7.6 mill.
Laterals	Tsh 11.1 mill.
Plot connections	Tsh 9.7 mill.
Investment phase 1	Tsh 38 0 mill.

Phase 2: 1984 - 1989.

In this phase the central sewerage system is expanded so as to include new residential and industrial areas Within the existing areas more plot connections are constructed, and more schools, hotels and other public and commercial premises are connected. As in phase 1, the residential areas account for 70% of the investments in sewage treatment, trunk and main sewers.

Operation and Maintenance·

Approximately 9,000 pits or tanks are assumed to be emptied by 4 vacuum trucks, of which one is a combined vacuum truck/jet cleaner. Two labour teams run the sewage treatment ponds, and three labour teams run the sewer cleaning.

Total operation and maintenance cost: Tsh 1,770,000/year.

x) Amortizing factor at 10% over 20 years

Investment:

Available in 1989: Tsh 10.99 mill/year.

The increase in operation and maintenance cost is:

1.77 - 0.95 = Tsh 0.82 mill/year.

Investment size for phase 2: (10.99 - 0.82) x 8.5136 = Tsh 86.6 mill.

Table 7.1 shows the number of plots constructed in each area, and fig. 7.3 shows the sewerage system at the end of phase 2.

The investment is utilized as follows:

Sewage treatment and trunk sewers	Tsh 14.0 mill.
Main sewers	Tsh 9.6 mill.
Laterals	Tsh 33.5 mill.
Plot connections	Tsh 29.5 mill.
Investment phase 2	Tsh 86.6 mill.

Phase 3: 1989 - 2009

The central sewerage system is further expanded, and more plots are connected. Residential areas account for 70% of the trunk sewer investment. To the west a sewerage system is constructed in catchment area A (see fig. 6.2), and only residential areas are connected to this system. To the east a sewerage system is constructed in catchment area D, and catchment area E is connected to this through a pump station. All three sewerage systems drain to a sewage treatment plant constructed as an oxidation ditch. Sludge collected from wet pits and septic tanks is disposed of in the now disused sewage treatment ponds.

Operation and Maintenance.

It is assumed that approximately 32,000 plots will be served by 14 vacuum trucks. Four labour teams run the oxidation ditch plant, and eight labour teams run the sewer cleaning.

Total operation and maintenance cost. Tsh 5,740,000/year.

Investment:

Available: Tsh 60.43 mill/year.

Investment size for phase 3:

(60.43 - 5.74) x 8.5136 = Tsh 465.6 mill.

Investments in central sewerage system:

Trunk sewers	Tsh 3.2 mill.
Main sewers	Tsh 9.1 mill.
Laterals	Tsh 20.9 mill.
Plot connections	Tsh 18.4 mill.
Total investments in central sewer system	Tsh 51.6 mill.

Investment in western sewerage system:

Assume 60% connections in existing settlement areas and 20% connections in new development areas, giving a total of 10,400 plots connected. The trunk and main sewer system is designed for 150.000 people.

Trunk sewers	Tsh 37.4 mill.
Main sewers	Tsh 28.1 mill.
Laterals	Tsh 49.8 mill.
Plot connections	Tsh 43.7 mill.
Total investments in western sewerage system	Tsh 159.0 mill.

Investments in eastern sewerage system:

Assume 55% connections in existing settlement areas and 10% connections in new low-density development areas, giving a total of 9,500 plots connected. The trunk and main sewer system is designed for 150,000 people.

Trunk sewers and pumping station	Tsh 37.2 mill.
Main sewers	Tsh 27.9 mill.
Laterals	Tsh 45.2 mill.
Plot connections	Tsh 39.7 mill.
Total investments in eastern sewerage system	Tsh 150.0 mill.

Investment in sewage treatment, oxidation ditch:

According to table 7.1 approximately 300,000 people are connected to the sewerage systems discharging to the oxidation ditch. Industries, schools, hospitals, hotels, etc. are also discharging to this oxidation ditch. Cost estimates for the oxidation ditch are expressed in Tsh per p.e., though, and the investments in the oxidation ditch for the residential area is, at Tsh 350/p.e.:

Oxidation ditch	Tsh 105 mill.

Total investments, phase 3:

Central sewerage system	Tsh 51.6 mill.
Western sewerage system	Tsh 159.0 mill.
Eastern sewerage system	Tsh 150.0 mill.
Sewage treatment, oxidation ditch	Tsh 105.0 mill.
Investments, phase 3	Tsh 465.6 mill.

Main Advantages and Disadvantages

Advantages

Good control of effluent from industries, hospitals and high-density residential areas. On-site disposal of industrial and hospital effluent would be almost impossible, and a system of vaults and vacuum trucks would be required to remove the effluent. This would, however, seriously hamper the development of the industries, as there would be a practical limit to the amount of wastewater which could be disposed of.

Any on-site disposal or handling of hospital effluent would pose a serious health risk whereas disposal in a sewerage system provides a safe control.

Plots with house-connected water in high-density areas can be connected to the sewerage system and discharge a large proportion of water (> 150 l/cap/day).

Disadvantages

After the initial 5 years only 18% of the plots will be connected to the sewerage system, and after 30 years the percentage is lower than 50. All the unconnected households will have to solve their wastewater disposal problems themselves.

Low-income areas, especially to the west, having malfunctioning existing facilities and bad ground conditions, are considered only by the provision of vacuum trucks during the two early phases. Very bad sanitation conditions and a great health risk (cholera, typhoid, etc.) will continue to be a predominant feature in these areas.

The development of the sewerage system implies the necessity of a similar development of the water supply system. If the water consumption is too low, the wastewater flow will be insufficient to transport excreta and other solids, resulting inevitably in blockages of the sewers.

The investments per connected plot are:

Phase 1:	Tsh 16,450
Phase 2:	Tsh 13,350
Phase 3:	Tsh 17,580.

These figures are all within the total construction cost per household of \$600 - \$4000 which the World Bank found in studying conventional sewerage systems in eight cities /8/. If the households were supposed to pay for themselves when connected, only income group IV could afford a connection. When all are paying as proposed here, there is a cross-subsidization during the early two phases from income group I and IV to income group II and III. In phase 3 there is a general cross-subsidization from non-benefitters to benefitters. This could create political problems.

The possibility exists that the housing standard in income group I does not justify the provision of a cistern-flushed toilet and a sewerage connection, even though income group I areas are not connected until phase 3.

The planning, design and construction of a sewerage scheme implicates for a developing country materials and skilled manpower to be derived from outside countries, which means expenditure of foreign exchange.

The protection of the sewers against sulphuric acid corrosion is a special problem for urban areas in hot climates, which can increase the cost of the pipes considerably.

Tables and Figures

Table 7.1 shows for each phase the number of plots connected to a sewerage system in a residential area. The tables also show the total numbers of plots connected for each phase in relation to the overall total number of plots.

Table 7.2 shows the percentage connected in each phase for each of the four income groups and indicates the corresponding investment.

The results from table 7.2 are illustrated in figure 7.1 showing investments in Tsh per plot.

Figures 7.2, 7.3 and 7.4 illustrate the alignment of the sewerage system in each phase and the connection rate for each area.

Alternative 1

Table 7.1: RESIDENTIAL AREAS CONNECTED TO SEWERAGE SYSTEM

Area Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Income Group		IV	III	III	III	III	III	IV	I	II,III	II	I,II	II	III	II	III	IV	IV
Investment Period																		
Phase 1 1979-1984	Plots connected	400	500	180	110	0	470	0	0	250	400							
	Total Plots	871	689	211	227	356	856	1062	1537	294	784	1851	1202	20	578	220	238	307
% connected		46	73	85	48	0	55	0	0	85	51	0	0	0	0	0	0	0
Phase 2 1984-1989	Plots connected	471	189	31	117	356	386			44	384	1000	800	20	420	140	100	
	Total Plots	871	689	211	227	356	856	1151	1537	294	784	1851	1202	20	578	220	238	307
% connected		54	27	15	52	100	45	0	0	15	49	54	67	100	73	64	42	0
Total % connected		100	100	100	100	100	100	0	0	100	100	54	67	100	73	64	42	0
Phase 3 1979-2009	Plots connected							691	922			400	200		389	20	40	
	Total plots	871	689	211	227	356	856	1151	1537	294	784	2380	1546	20	809	220	238	307
% connected		0	0	0	0	0	0	60	60	0	0	17	13	0	48	9	17	0
Total % connected		100	100	100	100	100	100	60	60	100	100	59	65	100	100	73	59	0

Alternative 1

Table 7.1 continued: RESIDENTIAL AREAS CONNECTED TO SEWERAGE SYSTEM

Area Number		18	19	20	48	49	50	52	53	55	57	60	61	Future Unnumbered Residential Areas				Total connected
Income Group		IV	III	IV	III	I	I,II	II,III	IV	II	II	II	III	I	II	III	IV	
Investment Period																		
Phase 1 1979-1984	Plots connected																	2310
	Total Plots	131	54	409	673			342										12912
% connected		0	0	0	0			0										18
Phase 2 1984-1989	Plots connected				966			600	1000									7024
	Total Plots	131	77	409	1046	1811	2327	655	1716									19564
% connected		0	0	0	92	0	0	92	58									36
Total % connected		0	0	0	92	0	0	92	58									48
Phase 3 1989-2009	Plots connected				300	1397	3355	27	1402	2266	200	3317	2205	1800	1800	1800	1707	24738
	Total Plots	131	77	409	1345	2328	5592	627	2402	2832	227	6031	4009	8556	3403	9102	12481	72048
% connected		0	0	0	22	60	60	4	58	88	80	55	55	21	53	20	14	34
Total % connected		0	0	0	94	60	60	100	100	80	88	55	55	21	53	20	14	47

Alternative 1

Table 7.2: DISTRIBUTION OF INVESTMENTS

Income Group		I		II		III		IV			
Investment Period		% Connected of Total Plots	Investment Mill. Tsh	% Connected of Total Plots	Investment Mill. Tsh	% Connected of Total Plots	Investment Mill. Tsh	% Connected of Total Plots	Investment Mill. Tsh	Total Connected	Total Investment Mill. Tsh
Phase 1 1979-1984		0%	0	5.1%	10.7	9.8%	20.7	3.1%	6.6	18%	38
Phase 2 1984-1989		0%	0	13.3%	32.1	14.6%	35.2	8.1%	19.3	36%	86.6
	Accumulated Totals	0%	0	15.4%	42.8	22.3%	55.9	10.1%	25.9	48%	124.6
Phase 3 1989-2009		10.4%	144.1	11.9%	164.9	6.0%	83.2	5.3%	73.4	34%	465.6
	Accumulated Totals	10.4%	144.1	15%	207.7	13.3%	139.1	8.0%	99.3	47%	590.2

FIG. 71
ALTERNATIVE 1, SEWERAGE SYSTEMS

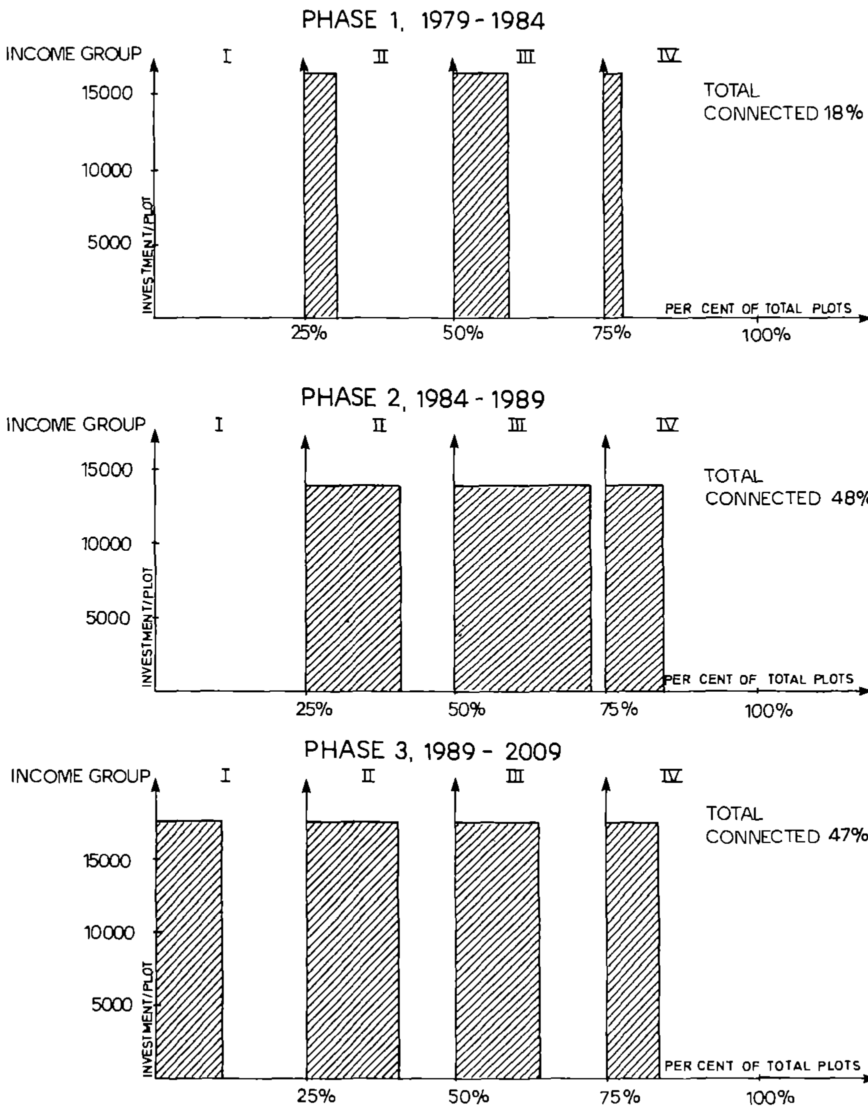


FIG. 7.2
ALTERNATIVE 1, SEWERAGE SYSTEM
PHASE 1, 1979 - 1984

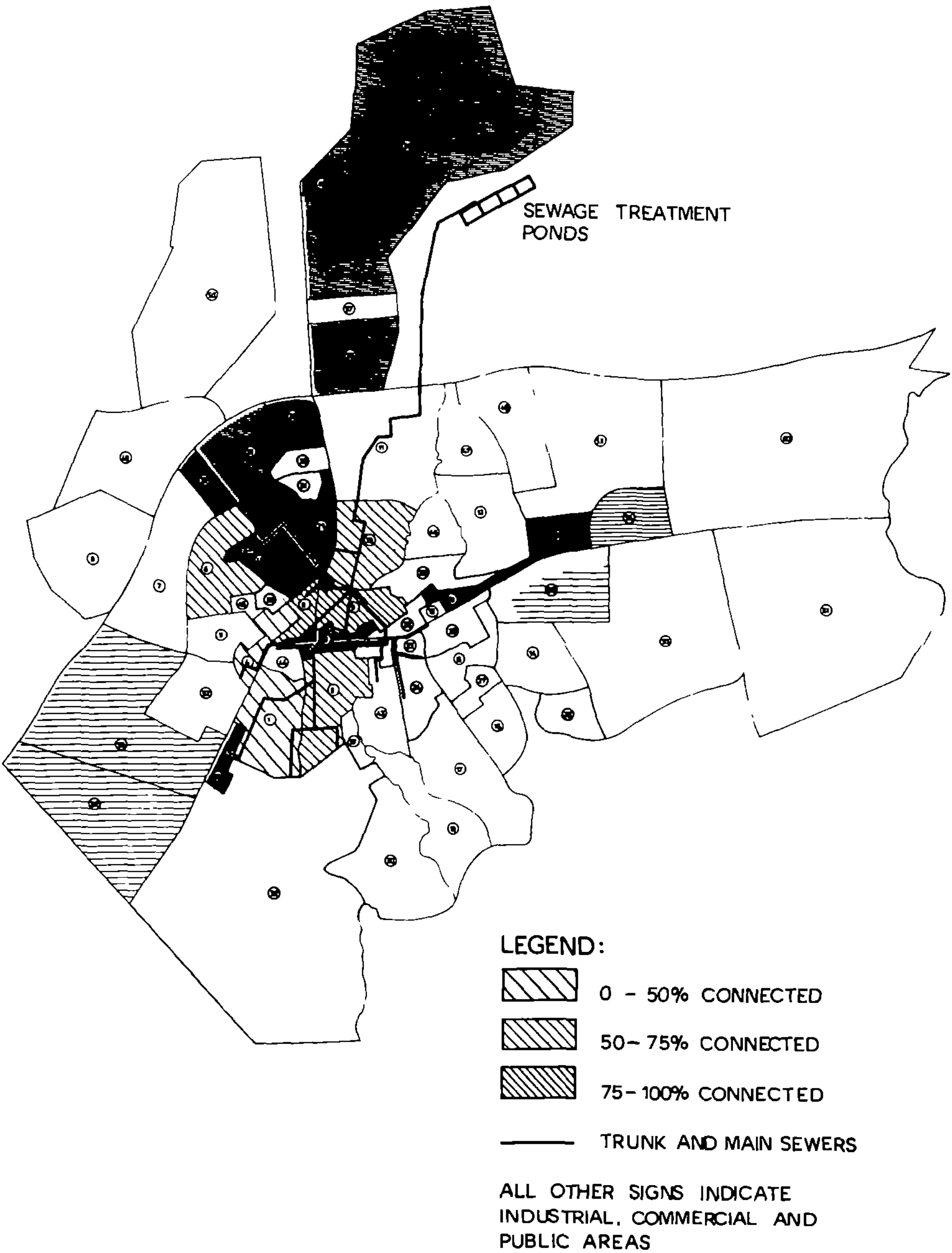


FIG. 73
ALTERNATIVE 1, SEWERAGE SYSTEM
PHASE 2, 1984-1989

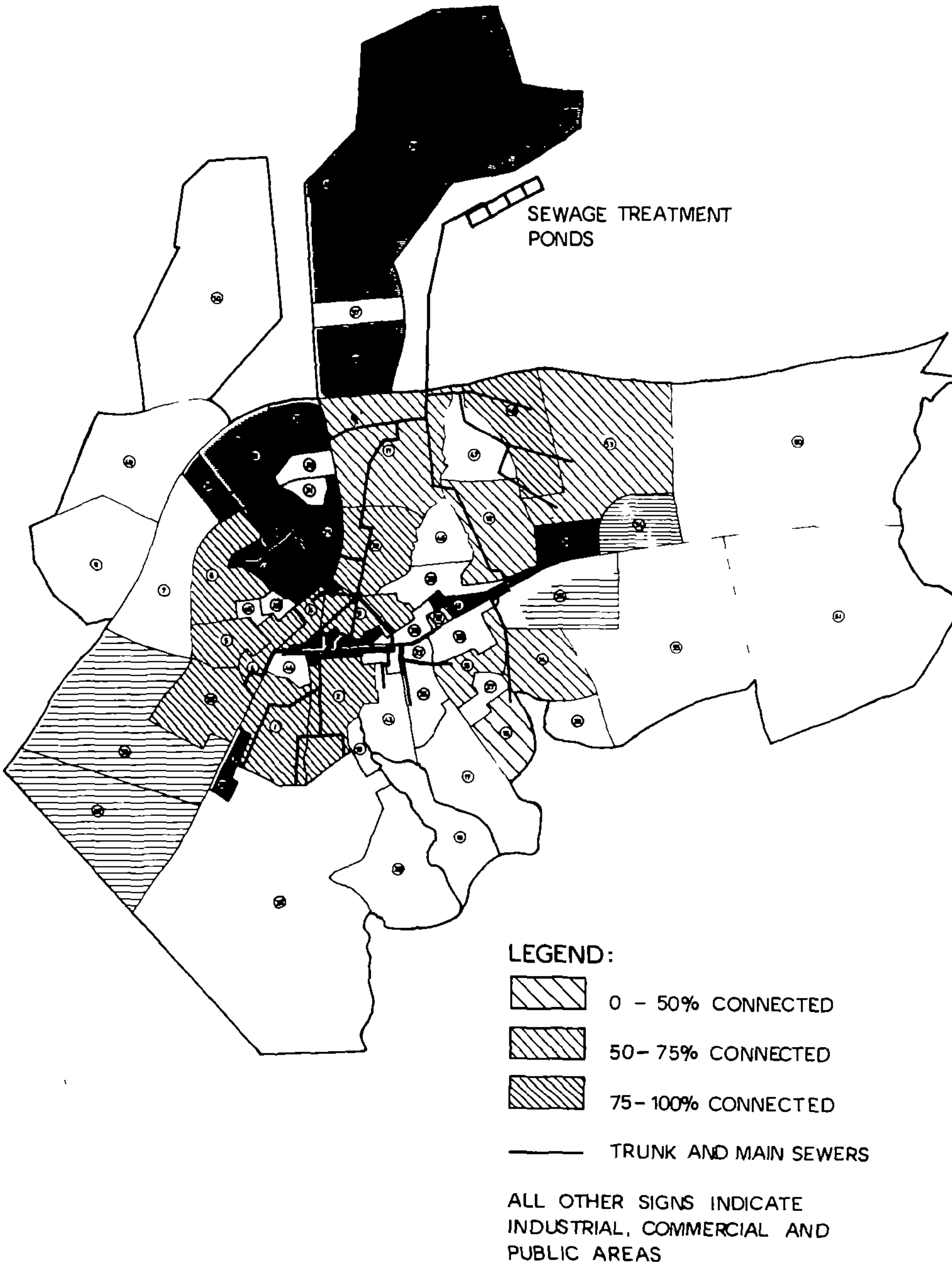
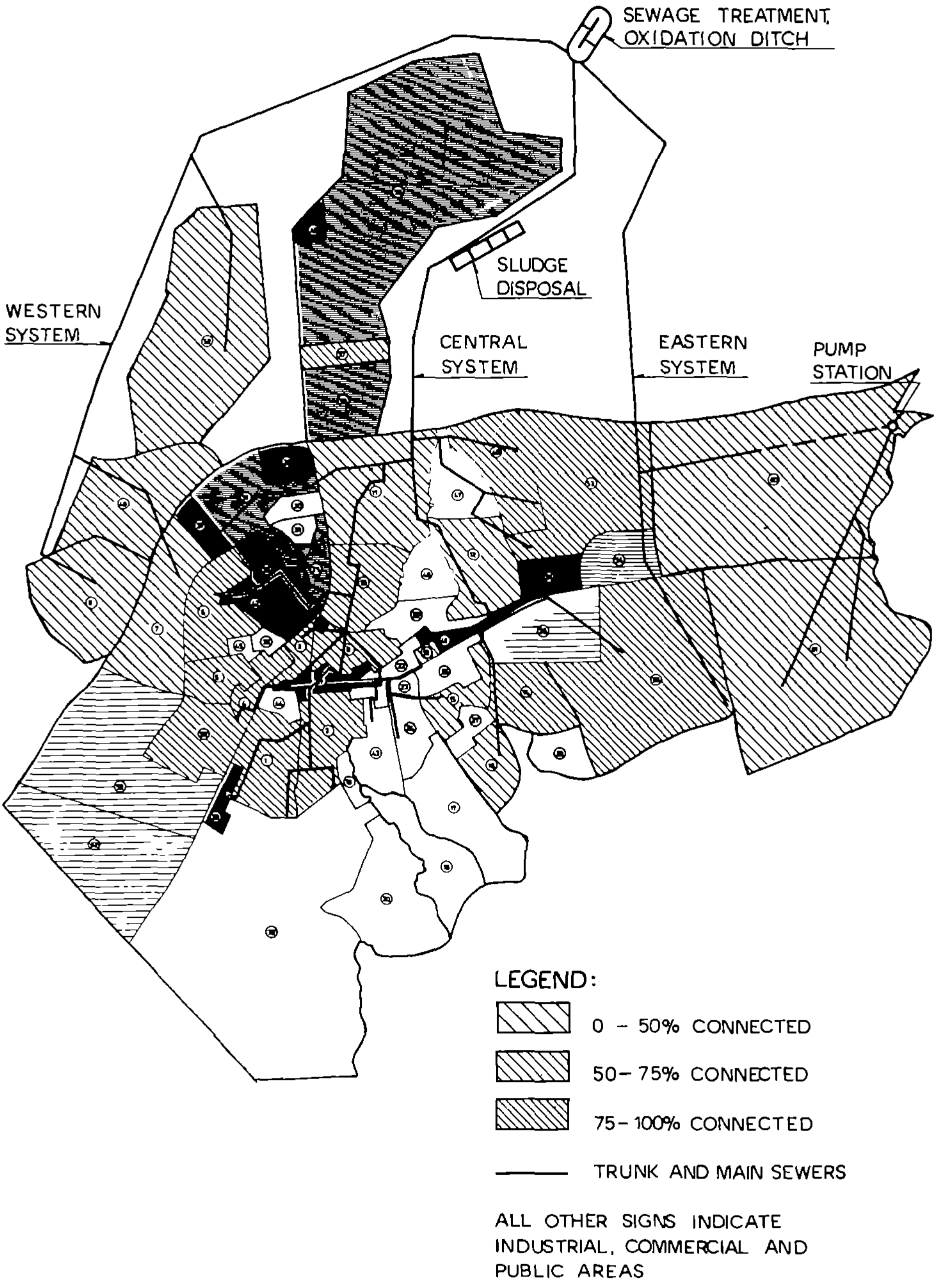


FIG 74
ALTERNATIVE 1. SEWERAGE SYSTEM
PHASE 3, 1989 - 2009



8. ALTERNATIVE 2

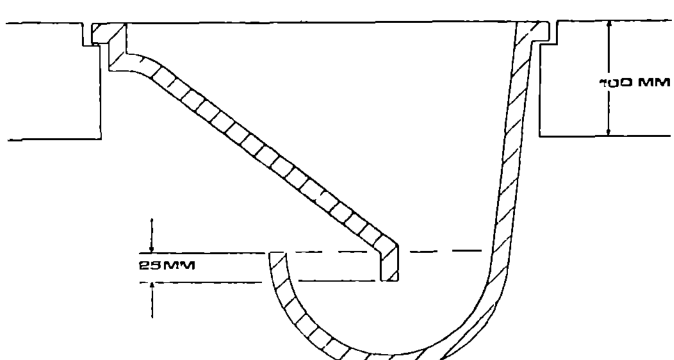
On-Site Disposal Systems

In this alternative all plots are provided with the best sanitation systems possible if all plots are to share systems to the same sanitation standard. During the first phase only plots having systems which do not function very well, and new plots are provided with new sanitary systems. During phase 2 systems constructed before 1979 are replaced by new systems except for well-functioning septic tank systems. By the end of phase 3 all plots including newly established plots attain the highest service level possible considering the proposed investment sizes.

Sanitation Systems

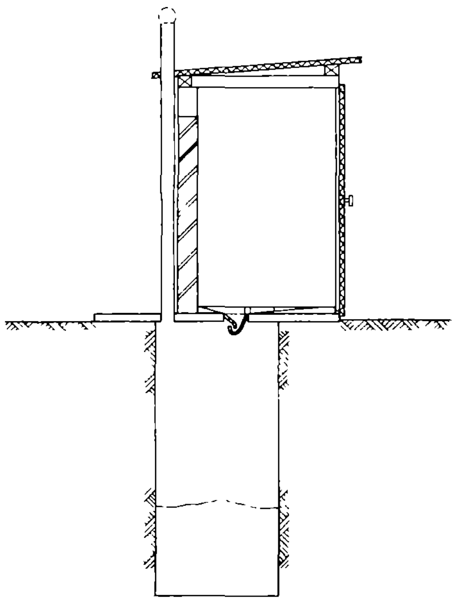
For areas in which virtually everybody uses water for anal cleansing, the pour-flush systems constitute a very appropriate sanitation technology. The pour-flush bowl provides a water seal preventing the development of odour and the breeding of insects. It is important that the tradition of using water for anal cleansing prevails because the use of corncobs, sticks, newspapers etc. will result in the water seal not being flushed; the seal will be blocked, and the sanitation system will be of no avail. The sanitation survey conducted in July 1979 by the Tanzanian Ministry of Lands, Housing and Urban Development /1/ found that water was used for anal cleansing by virtually everybody, consequently, pour-flush systems are technically appropriate for Morogoro.

The pour-flush bowl or water seal unit is shown below.



In this alternative 6 different types of pour-flush systems are proposed:

TYPE A

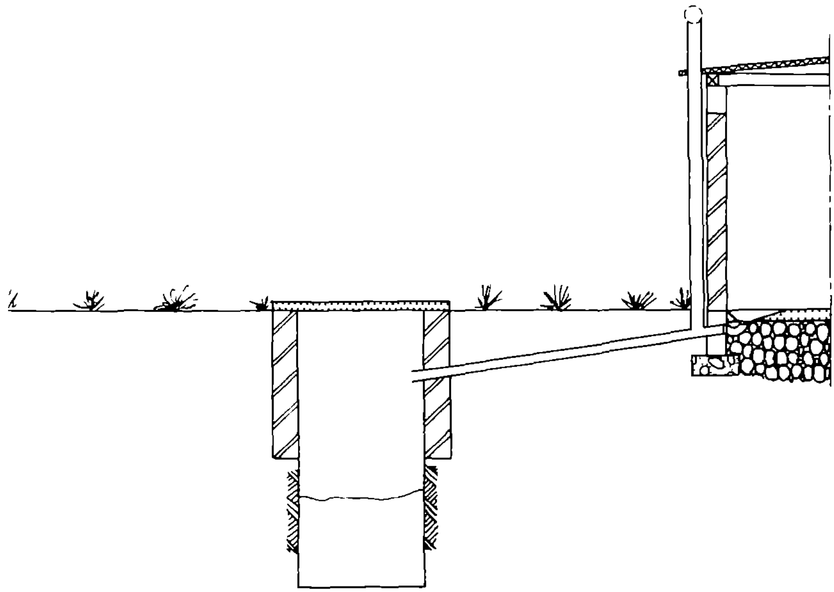


Ventilated pit latrine, used where:
- rock deeper than 2,5m
- ground water deeper than 2,0m

This is a normal ventilated pit latrine with a pour-flushed bowl located in the squatting plate. Approximately two litres of water is used for flushing a stool. 3 visits per day per user and 9 users per latrine yield a water discharge into the pit of 54 litres per day; 54 litres can easily soak away in the pit under reasonable ground conditions.

This type can be upgraded to TYPE B as long as the pit is in a good condition and not filled up. If the pit is filled, it could be emptied as part of an upgrading to TYPE B.

TYPE B



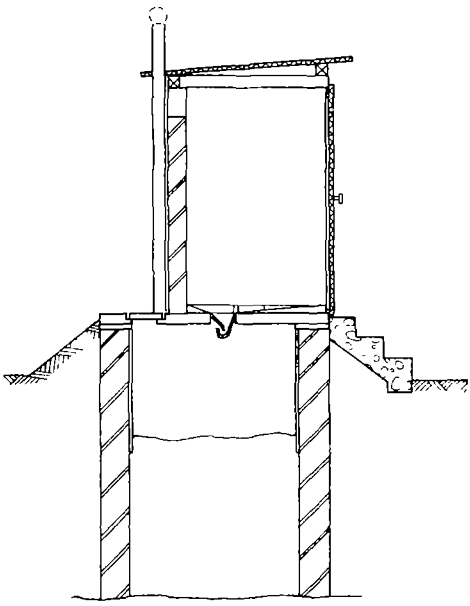
Off-set pit latrine, used where :
- rock deeper than 2,5m
- ground water deeper than 2,0m

The squatting plate with flush-bowl is not located on top of the pit, but in a small building next to the covered pit or located inside the house. A pipe connects the squatting plate and the pit.

The off-set pit latrine can be upgraded by converting the existing pit to a septic tank TYPE E and constructing a drainfield. The amount of work to be done on the pit depends on ground conditions and the condition of the pit structure.

Connection to a sewerage system is possible by installing a cistern flushing system and naturally bypassing the pit.

TYPE C

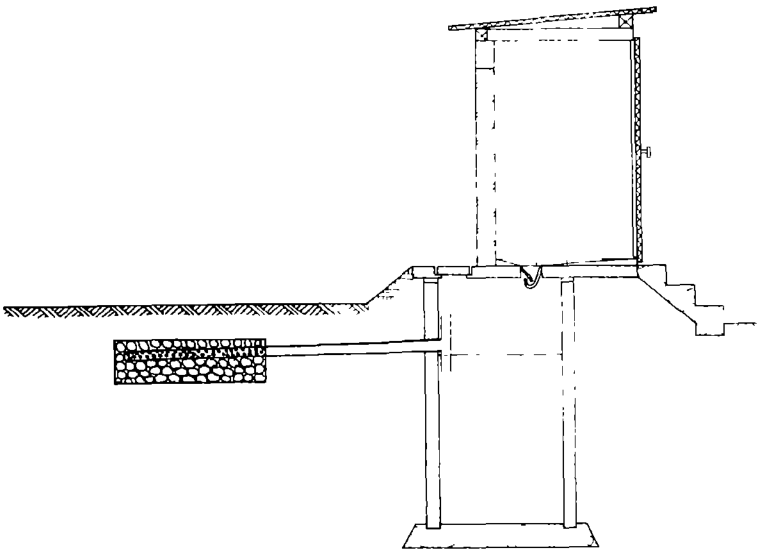


Elev. vent. improved pit latrine, used where:
- rock 1-2m below surface
- ground water 1,5 - 2,5m below surface

Where ground conditions are less favourable, an elevated ventilated improved pit latrine is used. The pit is lined with bricks which are rendered at the top, but open at the bottom to allow soakage.

The elevated pit can be used when upgrading to TYPE B or even TYPE E. This, however, will depend on the elevation of the new house in which the squatting plate is to installed, as gravity flow must be ensured.

TYPE D



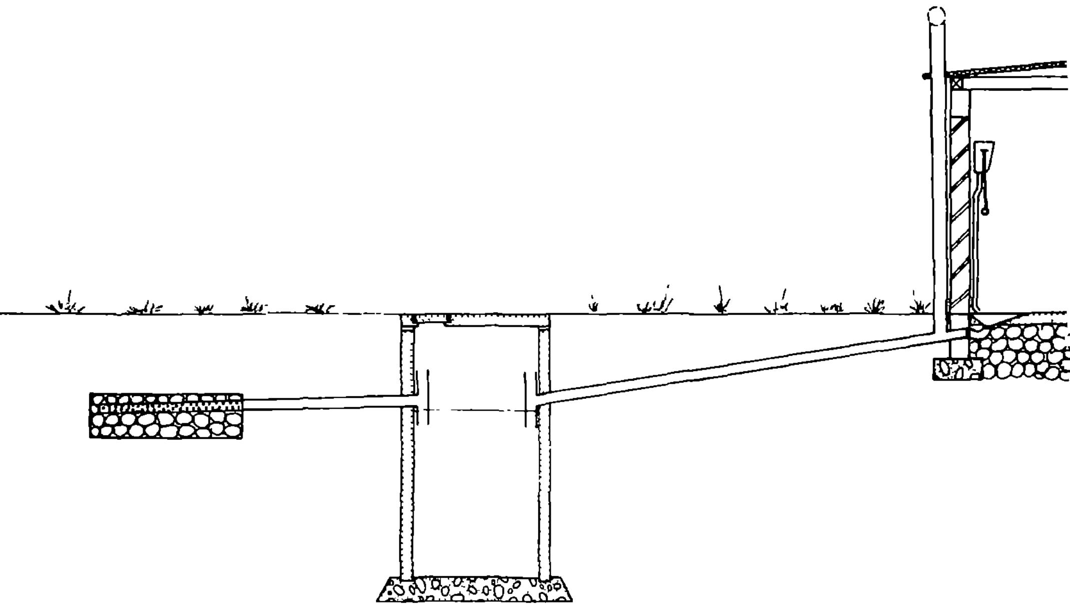
Aqua privy, used where
- rock < 1,5m below surface
- ground water 0,3 - 1m below surfase

This type resembles the aqua privy, but instead of a tube leading into the concrete tank a pour-flush bowl is located in the squatting plate. In this type the water seal is much better secured than in an aqua privy in which a tank leakage would break the water seal and result in malfunction

This type is used in areas with extremely bad ground conditions. Surplus water from the tank is led to an infiltration drain and introduced close to the ground surface.

TYPE D aqua privy can be upgraded to TYPE E septic tank if the building containing the new squatting plate is elevated so as to make gravity flow possible.

TYPE E

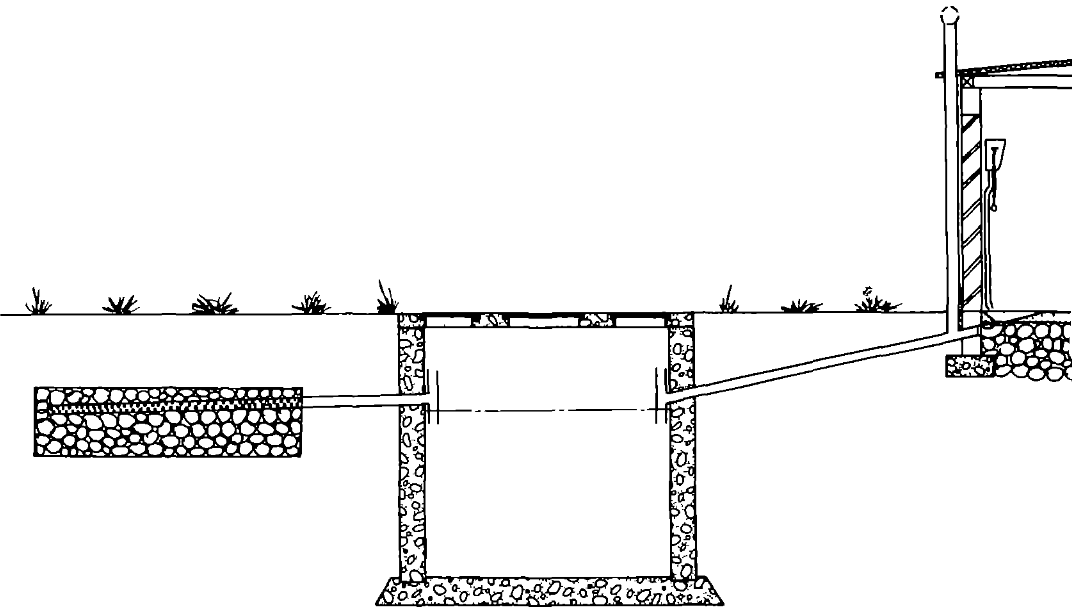


This is in fact a small septic tank with a drain-field,designed for a water discharge not exceding 70 l/cap/day. The toilet is either hand or cistern flushed and located inside the house. The septic tank itself is a diameter 1.5 m precast concrete ring on an in-situ cast concrete bottom. The drain-fiel is designed for the distribution of a maximum of 1 m^3 per day.

Upgrading from TYPE E to TYPE F involves the construction of an extra similar-sized tank or a complete new on-site cast tank. Further the drainfield must be extended.

The septic tank and drainfield is bypassed when connecting to a sewerage system except for cases in which the plot connection is laid at such a flat grade that it is desirable to keep the septic tank for the retention of solids.

TYPE F



This is a standard septic tank with drain-field. The whole unit is designed for the treatment of 150 l/cap/day. The tank is constructed from in-situ concrete. This type allows the connection of one or more cistern-flushed toilets located inside the house.

Connection to a sewerage system can be made as described under TYPE E. This septic tank is very expensive. Unless the tank is useful for the retention of solids before a sewer connection at a flat gradient, there will be a great loss in investments when bypassing the septic tank and drainfield a few years after construction.

Cost Estimates

The cost estimates for the six sanitation systems have been derived from the Preliminary Design Report /1/ for Morogoro (see Appendix E). The pour-flush bowl is estimated at Tsh 500. It is made of galvanized steel, vitrified clay or concrete. For contingencies 20% has been added. The estimates do not include house installation or superstructures. Neither is any upgrading from one type to another included.

TYPE A:	2000 x 1.2 = Tsh 2,400
TYPE B:	3000 x 1.2 = Tsh 3,600
TYPE C:	4500 x 1.2 = Tsh 5,400
TYPE D:	5000 x 1.2 = Tsh 6,000
TYPE E:	5800 x 1.2 = Tsh 7,000
TYPE F:	12000 x 1.2 = Tsh 14,400.

Phasing of the On-site Disposal Systems

Phase 1: 1979 - 1984

90% of septic tank systems in income group IV areas are well-functioning. The remaining 10% plus all new plots in some of the income IV group areas have type F constructed.

Areas with bad sanitation conditions (see fig. 6.6) and bad ground conditions (see fig. 6.3) have facilities TYPE A, B, C or D constructed for all plots.

In areas with good sanitation conditions, good ground conditions and not belonging to the income group I area, 60-80% of existing facilities are maintained. Type A or B is provided.

In low-income areas (income group I and II) and high-density areas 80% of the plots is provided with new facilities TYPE A, B, C or D. Some pit latrines will still be useful, and some of the new facilities are shared by two plots.

Collected sludge is disposed of in anaerobic ponds.

Operation and Maintenance:

During the initial five years existing wet pits and septic tanks are to be emptied together with the additionally constructed pits (TYPE C, D and E). Two vacuum trucks are required to serve 4,500 plots and one labour team to run the anaerobic ponds.

Total operation and maintenance	Tsh 900,000/year

Investment:

The amount available 1984 is Tsh 5.42 mill/year.

Investment size for phase 1:

$$(5.42 - 0.90) \times 8.5136 = \text{Tsh } 38.5 \text{ mill.}$$

Table 8.1 gives the distribution of each number of types provided shown in fig. 8.2. The investment is utilized as follows:

TYPE A:	2400	x	4424	=	Tsh 10.6 mill.
TYPE B:	3600	x	992	=	Tsh 3.6 mill.
TYPE C:	5400	x	386	=	Tsh 2.1 mill.
TYPE D:	6000	x	1722	=	Tsh 10.3 mill.
TYPE F:	14400	x	810	=	Tsh 11.7 mill.
					Tsh 38.3 mill.
Anaerobic ponds:					Tsh 0.2 mill.
Investment phase 1					Tsh 38.5 mill.

Phase 2: 1984 - 1989

5% af the septic tanks constructed before 1979 are replaced, in some income group IV areas new plots are provided with TYPE F septic tanks.

All other new plots are provided with TYPE E septic tanks.

All plots with facilities constructed before 1979 are provided with TYPE E septic tanks (except for areas with TYPE F septic tanks).

Collected sludge is treated in anaerobic ponds.

Operation and Maintenance:

As emptying is to be provided for 13,500 plots, 6 vacuum trucks will be needed and two labour teams to run the anaerobic ponds.

Total operation and maintenance Tsh 2,350,000/year

Investment:

The amount available in 1989 is Tsh 10.99 mill/year.

The increase in operation and maintenance cost is:

2.35 - 0.9 = Tsh 1.45 mill/year.

Investment size for phase 2:

(10.99 - 1.45) x 8.5136 = Tsh 81.2 mill.

According to table 8.1 the investment is utilized as follows:

TYPE E:	7000 x 10548 =	Tsh 73.8 mill.
TYPE F:	14400 x 482 =	Tsh 7.0 mill.
		Tsh 80.8 mill
Anaerobic ponds:		Tsh 0.4 mill.
Investment phase 2		Tsh 81.2 mill.

Phase 3: 1989 - 2009

All existing and new plots are to have TYPE E septic tanks except for some income group IV areas where TYPE F septic tanks are provided.

The minimum sanitation standard is thus provided by a TYPE E septic tank.

No sewerage system is constructed.

Collected sludge is disposed of in anaerobic ponds.

Operation and Maintenance:

All 72,000 plots have by now tanks to be emptied once every 5 years. This means that 32 vacuum trucks will be needed. Three labour teams run the anaerobic ponds.

Total operation and maintenance	Tsh 11,000,000/year

Investment:

The amount available in 2009 is Tsh 60.43 mill/year.

Investment size for phase 3:

(60.43 - 11.00) x 8.5136 = Tsh 420.8 mill.

According to table 8.1 the investment is utilized as follows:

TYPE E:	7000 x	58256 =	Tsh 407.8 mill.
TYPE F:	14400 x	708 =	Tsh 10.2 mill.
			Tsh 418.0 mill.
Anaerobic ponds			Tsh 2.8 mill.
Investment phase 3			Tsh 420.8 mill.

Main Advantages and Disadvantages

Advantages

The first phase acts as an 'immediate action' sanitary programme. Areas with malfunctioning sanitary systems and all new plots are provided with a new sanitary system within the initial five years. As the proposed on-site disposal systems offer a high level of protection against health hazards from faecal matter, a protection against diarrhoeal diseases (cholera, typhoid, etc.) is quickly provided.

The parts of the on-site disposal systems which are important for the proper functioning: substructure, squatting plate and drainfields are professionally designed and constructed, whereas the superstructure is constructed by the user. Thus the user is directly involved, e.g. through a self-help scheme, but he is not responsible for the functional parts, which incidentally constitute the heavy work.

Investments are evenly distributed on income groups; this could have political advantages.

The water supply system can be slowly expanded, and the water requirement per user for the sanitation systems is low.

There is a good potential for the upgrading from sanitation TYPE A to TYPE B and from TYPE D to E.

Disadvantages

No control of effluent from industries, hospitals and high-density residential areas. On-site disposal in these areas has to be done in vaults, which must be emptied on a weekly basis or even more frequently. This sets a limit to the expansion of industries and hospitals.

The handling of hospital wastewater would pose a serious health risk.

As the water consumption increases, sullage disposal comes to be a problem, as there is a limit to the amount of wastewater which could possibly be soaked away. This applies to Morogoro because bad ground conditions prevail in many parts of this town.

Residents with a high building standard will demand connection to a large septic tank or a sewerage system.

Foreign exchange will be needed for the vacuum trucks.

A high degree of municipal participation is required to secure stable service and good vehicle maintenance.

An extensive soakage within a limited area implicates a high risk of groundwater contamination. In particular the possibility of building up nitrogen compounds prevails, which will reach the rivers because the rock is relatively shallow under the majority of the town.

If a sewerage system is to be initiated soon after phase 3, there will be a great loss in the investments made, particularly in phase 3.

Tables and Figures

Table 8.1 shows for each phase the sanitary types provided in each residential area. Also the total number of types provided is shown.

Table 8.2 shows the percentage provided with a sanitation unit for each income group in each phase. Also the corresponding investments are shown.

Table 8.2 is illustrated in figure 8.1 showing investments per plot.

Figures 8.2, 8.3 and 8.4 illustrate the distribution of the sanitation types provided for each area in each phase.

Alternative 2

Table 8.1: DISTRIBUTION OF SANITATION SYSTEMS IN RESIDENTIAL AREAS

Area Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Income Group		IV	III	III	III	III	III	IV	I	II,III	II	I,II	II	IV	II	III	IV	IV
Investment Period	Sanitation Type Provided																	
	Existing	283	139	31	34	146	526	572	431	29	219	521	336	2	388	141	161	196
	A		200	80	89	130	180		1106	165	285	400	720		190	50		
Phase 1	B	220	250	20		80	150							18		29		
1979 -	C											240	146					
1984	D	368	100	80	104					100	280	690						
	F							490									77	111
Total Plots		871	689	211	227	356	856	1062	1537	294	784	1851	1202	20	578	220	238	307
Phase 2	Existing	368	100	80	104	210	330	1069	1106	100	565	1330	864		190	79	218	282
1984 -	E	203	589	131	123	146	526		431	194	219	521	336	20	388	141		
1989	F	300						82									20	25
Total Plots		871	689	211	227	356	856	1151	1537	294	784	1851	1202	20	578	220	238	307
Phase 3	Existing	503	589	131	123	146	526	1151	431	194	219	521	336	20	388	141	238	307
1989 - 2009	E	368	100	80	104	210	330		1106	100	565	1859	1210		421	79		
Total Plots		871	689	211	227	356	856	1151	1537	294	784	2380	1546	20	809	220	238	307

Alternative 2

Table 8.1 continued: DISTRIBUTION OF SANITARY SYSTEMS IN RESIDENTIAL AREAS

Area Number		18	19	20	48	49	50	52	53	55	57	60	61	Future Unnumbered Residential Areas				Total Sanitation Type
Income Group		IV	III	IV	III	I	I,II	II,III	IV	II	II	II	III	I	II	III	IV	
Investment Period	Sanitation Type Provided																	
	Existing	119	15	289														4578
Phase 1	A		20		467			342										4424
1979 -	B		19		206													992
1984	C																	386
	D																	1722
	F	12		120														810
Total Plots		131	54	409	673			342										12912
Phase 2	Existing	111	39	374	673			342										8534
1984 -	E		38		373	1811	2327	313	1716									10548
1989	F	20		35														482
Total Plots		131	77	409	1046	1811	2327	655	1716									19564
Phase 3	Existing	131	38	409	373	1811	2327	313	1716									13083
1989 -	E		39		972	517	3265	314	686	2832	227	6031	4009	8556	3403	9102	11773	58257
2009	F																708	708
Total Plots		131	77	409	1345	2328	5592	627	2402	2832	227	6031	4009	8556	3403	9102	12481	72048

Alternative 2

Table 8.2: DISTRIBUTION OF INVESTMENT

Income Group		I		II		III		IV			
Investment Period	Sanitation Type Provided	% Connected of Total Plots	Investment Mill. Tsh	% Connected of Total Plots	Investment Mill. Tsh	% Connected of Total Plots	Investment Mill. Tsh	% Connected of Total Plots	Investment Mill. Tsh	Total Connected	Total Investment Mill. Tsh
	A	11.7%	3.7	13.2%	4.1	9.4%	2.9				
Phase 1	B					5.8%	2.7	1.8%	0.8		
1979 -	C	1.9%	1.3	1.6%	0.8						
1984	D	5.3%	4.1	2.9%	2.3	2.2%	1.7	2.8%	2.2		
	F							6.3%	11.7		
Totals		18.9%	9.1	17.2%	7.2	17.4%	7.3	10.9%	14.7	64.4%	38.3
Phase 2	E	19.6%	26.8	11.2%	15.3	13.2%	18.1	9.9%	13.7		
1984-1989	F							2.5%	6.9		
Totals		19.6%	26.8	11.2%	15.3	13.2%	18.1	12.4%	20.6	56.4%	80.8
Accumulated Totals		25%	35.9	25%	22.5	25%	25.4	19.6%	35.3	94.6%	119.1
Phase 3	E	18.7%	94.1	23.0%	115.8	21.4%	108.1	17.8%	89.8		
1989-2009	F							1.0%	10.2		
Totals		18.7%	94.1	23%	115.8	21.4%	108.1	18.8%	100	81.9%	418
Accumulated Totals		25%	130.0	25%	138.3	25%	133.5	24.1%	135.3	99.1%	537.1

FIG 81

ALTERNATIVE 2, ON-SITE DISPOSAL SYSTEMS

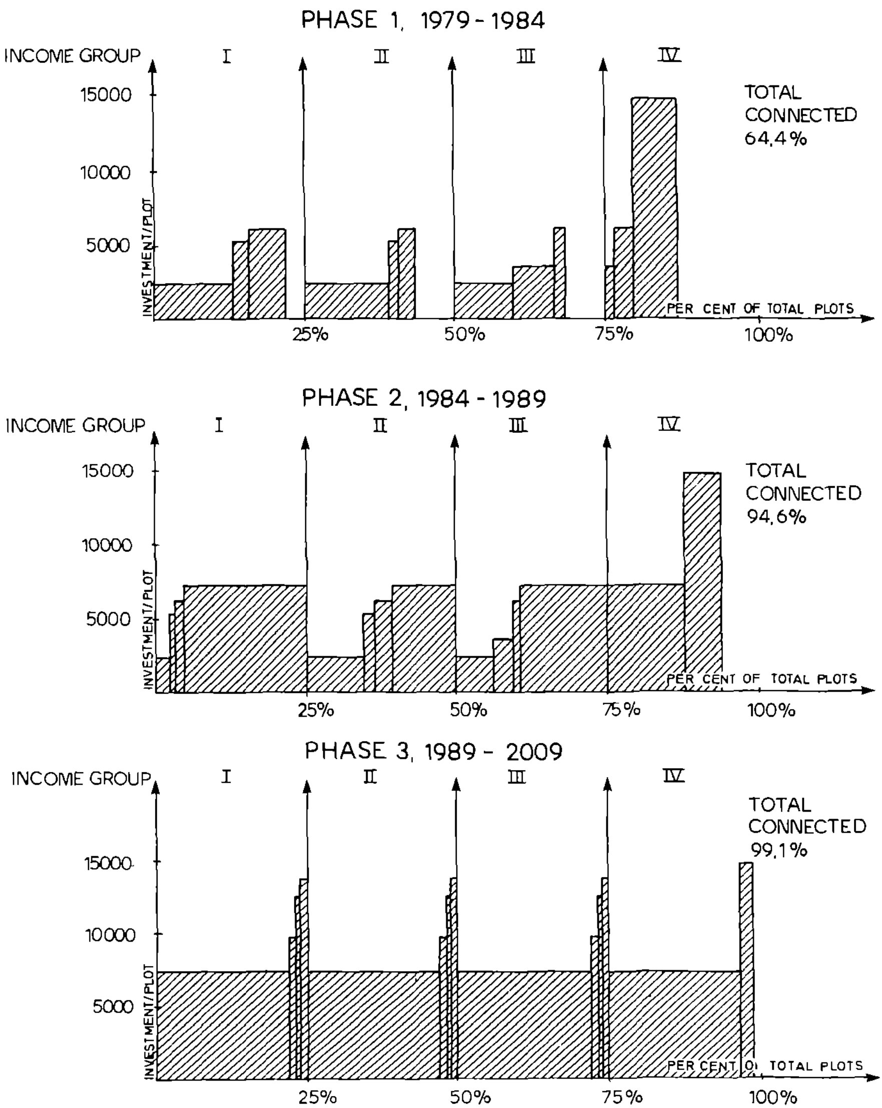
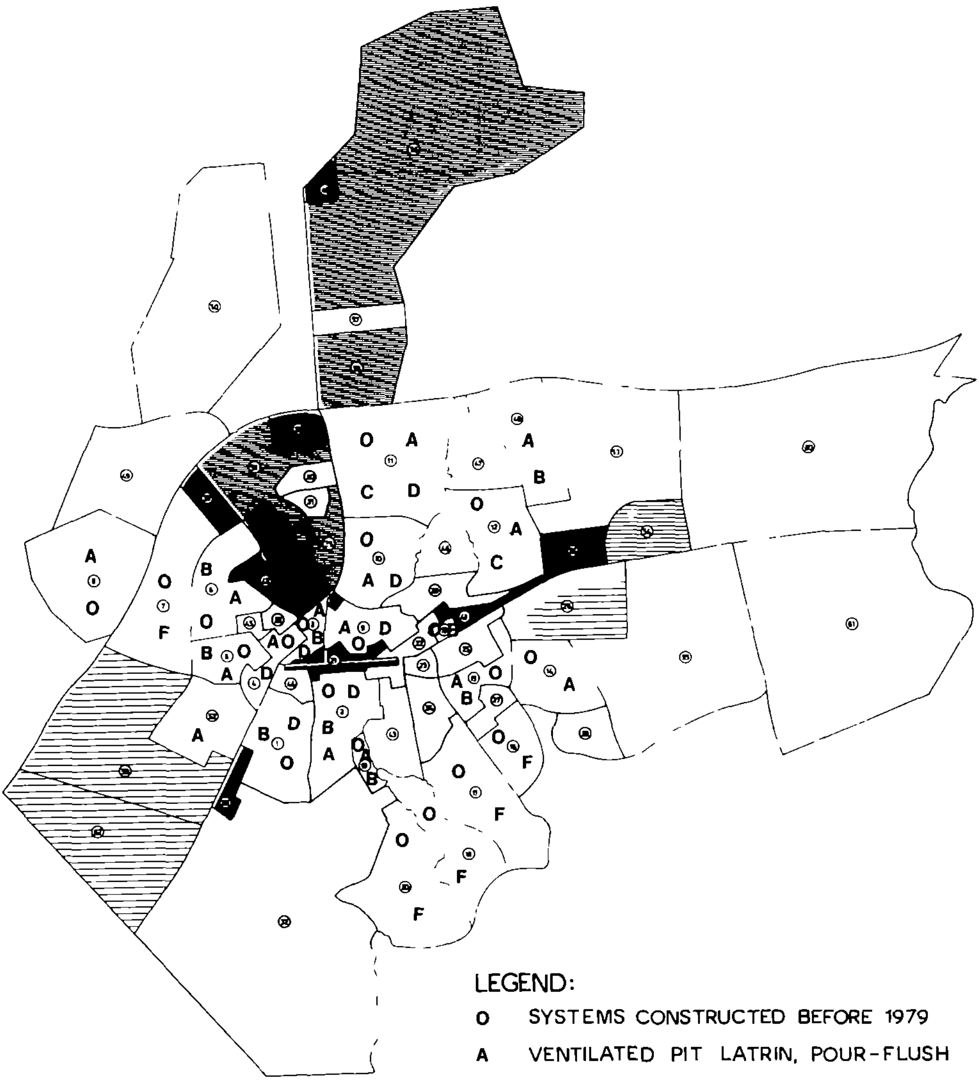


FIG 8 2

ALTERNATIVE 2, ON-SITE DISPOSAL SYSTEMS

PHASE 1, 1979- 1984



LEGEND:

O SYSTEMS CONSTRUCTED BEFORE 1979

A VENTILATED PIT LATRIN, POUR-FLUSH

B OFF-SET PIT LATRIN, POUR-FLUSH

C ELEVATED VENTILATED PIT LATRIN, POUR-FLUSH

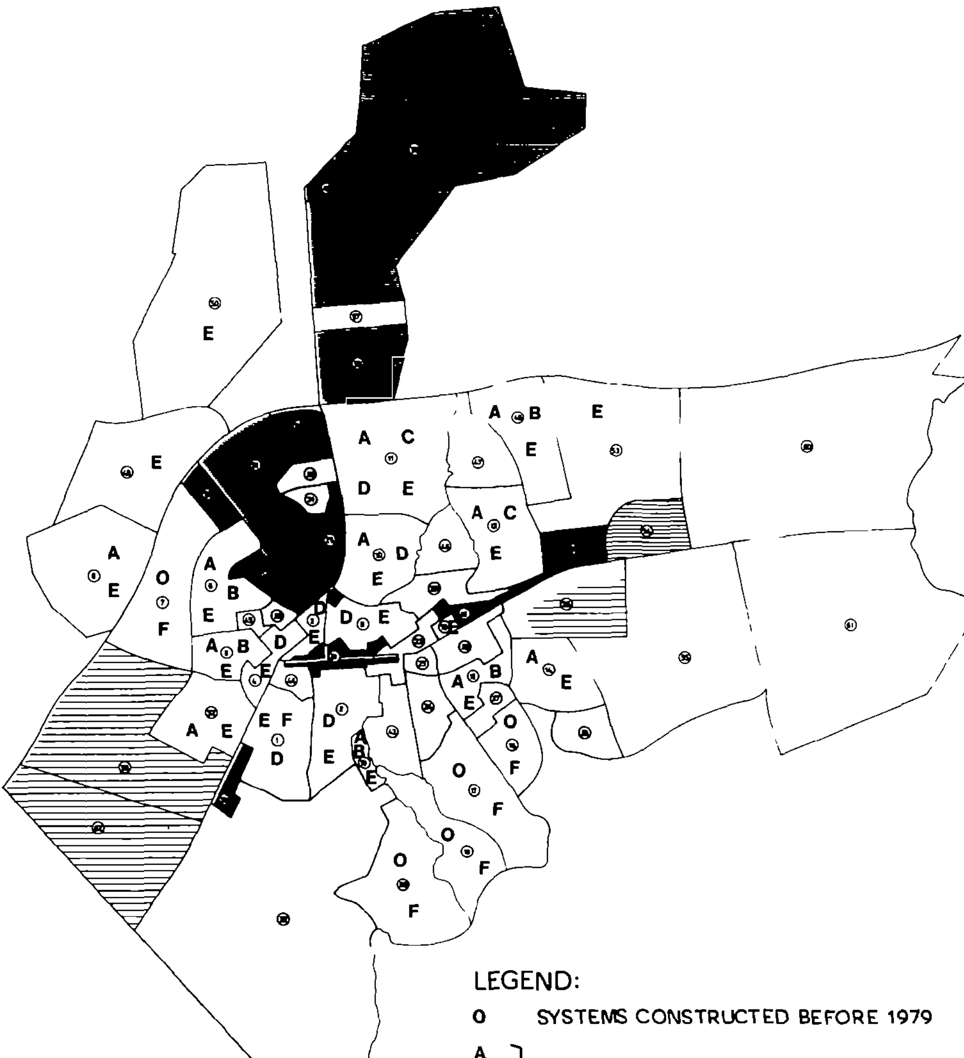
D AQUA PRIVI, POUR-FLUSH

F SEPTIC TANK-DRAINFIELD (150L/CAP/DAY)

FIG 8.3

ALTERNATIVE 2, ON-SITE DISPOSAL SYSTEMS

PHASE 2, 1984-1989



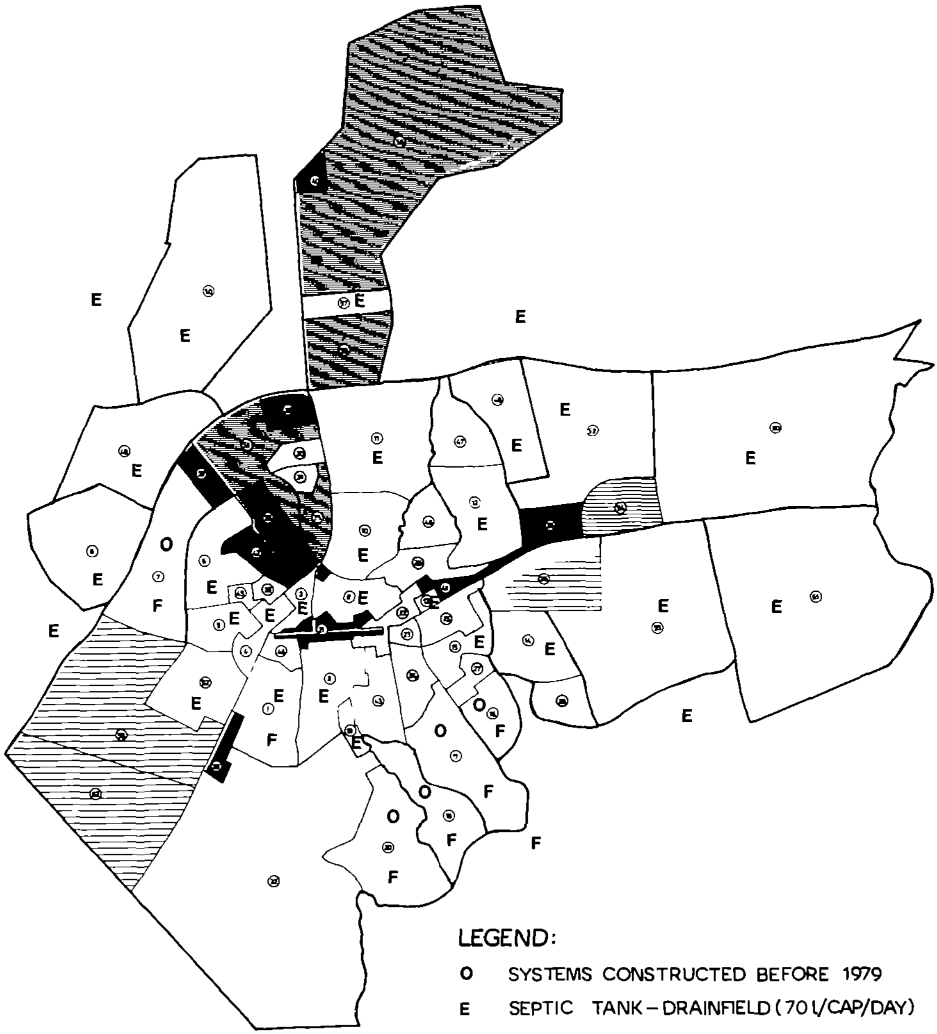
LEGEND:

- O SYSTEMS CONSTRUCTED BEFORE 1979
- A, B, C, D SYSTEMS CONSTRUCTED IN PHASE 1
- E SEPTIC TANK - DRAINFIELD (70l/CAP/DAY)
- F SEPTIC TANK - DRAINFIELD (150l/CAP/DAY)

FIG 8 4

ALTERNATIVE 2, ON - SITE DISPOSAL SYSTEMS

PHASE 3, 1989 - 2009



LEGEND:

O SYSTEMS CONSTRUCTED BEFORE 1979

E SEPTIC TANK – DRAINFIELD (70 l/CAP/DAY)

F SEPTIC TANK - DRAINFIELD (150 l/CAP/DAY)

9. ALTERNATIVE 3

Sewerage and On-site Disposal Systems

In this alternative it is suggested that every plot is provided with a well-functioning sanitation system as in alternative 2. The on-site disposal system proposed in this alternative does not provide the same service level as in alternative 2, though. This leaves, on the other hand, financial resources for investments in a sewerage system. The sewerage system is assumed to develop as in alternative 1, yet at a much slower rate. Thus no investments are made in the western sewerage system in phase 3.

Existing sanitation systems which are malfunctioning (high-water table, bad structure) are completely renewed.

As in alternative 1 the sewerage system follows the alignments and dimensions as set out in the preliminary design report by Cowiconsult/1/The proposed on-site disposal systems are identical to those described in alternative 2, where the reasons for using the pour-flush bowl are also given.

The central part of the town situated within catchment area B (see fig. 6.2) is sewered first connecting high-density residential areas, commercial, industrial and public areas. The sewage is treated in ponds. Where no sewerage connections are provided, the existing malfunctioning on-site disposal systems are replaced, and new plots have on-site disposal systems constructed. During phase 2 the central sewerage system is expanded, and nearly all disposal systems constructed before 1979 are replaced. Phase 3 includes the construction of an eastern sewerage system draining catchment area D (see fig. 6.2).

Cost Estimates

Unit prices used for the cost estimates in this alternative are identical to those used in alternative 1 and 2. Reference is made to appendix E and the Preliminary Design Report for Morogoro /1/.

Phasing of the Sewerage and On-Site Disposal Systems

Phase 1: 1979 - 1984

Industries and public areas are expected to be connected as in alternative 1.

Sludge collected from septic tanks and wet pits is disposed of in the sewage treatment ponds. Existing septic tank systems in income group IV areas are generally well-functioning. About 10% is renewed, and all new plots have TYPE E or F constructed.

Areas with malfunctioning sanitation systems (see fig. 6.6) and bad ground conditions (see fig. 6.3) have more than 50% of the existing systems replaced. TYPE A, B, C or D is provided, also for new plots.

In areas where many of the existing sanitary systems are functioning satisfactorily, 60-80% of these are maintained. TYPE A or B is provided.

In low-income high-density areas 60-80% of the plots are provided with new facilities TYPE A.

Operation and Maintenance:

All septic tanks and wet pits (TYPE C and D) require emptying, and two vacuum trucks are provided. One vacuum truck is a combined vacuum truck/jet cleaner also used for the maintenance of the sewers. One labour team runs the sewage treatment plant, and another team runs the sewer cleaning.

Total operation and maintenance cost: Tsh 900.000/year

Investment:

Available: Tsh 5.42 mill/year.

Investment size phase 1: (5.42 - 0.9) x 8.5136 = Tsh 38.5 mill.

Table 9.1 shows the number of plots in each area connected to the sewerage system or provided with an on-site disposal system.

The investment is utilized as follows:

Sewerage System:

Sewerage treatment and trunk sewers	Tsh 7.5 mill.
Main sewere	Tsh 2.2 mill.
Laterals	Tsh 2.3 mill.
Plot connections	Tsh 2.0 mill.
Total sewerage system	Tsh 14.0 mill.

On-Site Disposal System.

Type A: 2400 x 3164	Tsh 7.6 mill.
Type B 3600 x 900	Tsh 3.2 mill.
Type C: 5400 x 340	Tsh 1.8 mill.
Type D: 6000 x 1150	Tsh 6.9 mill.
Type E: 7000 x 424	Tsh 3.0 mill.
Type F: 14400 x 139	Tsh 2.0 mill.
Total on-site disposal systems	Tsh 24.5 mill.

Investment phase 1:	Tsh 38.5 mill.

Phase 2: 1984 - 1989

In this phase the central sewerage system is expanded so as to include new residential and industrial areas. Within the existing areas more plot connections are constructed, and more schools, hotels and other public and commercial premises are connected. On-site disposal systems TYPE A, B, C or D are provided depending on ground conditions.

All disposal systems constructed before 1979 are replaced except for well-functioning septic tanks in income group IV areas.

Some plots in income group III areas have building standards requiring TYPE E septic tanks.

TYPE E and F septic tanks are provided in income group IV areas.

Sewage and collected sludge is treated in the sewage treatment ponds.

Operation and Maintenance:

Approximately 12,000 plots have on-site disposal systems, for which emptying is required by vacuum truck. Another three trucks are provided, and an additional team is required to run the sewage treatment and one extra team to run the sewer cleaning.

Total operation and maintenance cost:	Tsh 2,100,000 year

Investment:

Available: Tsh 10.99 mill/year.

The increase in operation and maintenance cost is:

2.1 - 0.9 = Tsh 1.2 mill/year.

Investment size for phase 2: (10.99 - 1.2) x 8.5136 = Tsh 83.3 mill.

The investment is utilized as follows (cf. table 9.1):

Sewerage System:

Sewage treatment and trunk sewers	Tsh 6.4 mill.
Main sewers	Tsh 7.0 mill.
Laterals	Tsh 12.8 mill.
Plot connections	Tsh 11.3 mill.
Total investments in sewerage system	Tsh 37.5 mill.

On-Site Disposal Systems:

TYPE A:	2400 x 3171	Tsh 7.6 mill.
TYPE B:	3600 x 1613	Tsh 5.8 mill.
TYPE C:	5400 x 2871	Tsh 15.5 mill.
TYPE D:	6000 x 100	Tsh 0.6 mill.
TYPE E:	7000 x 1988	Tsh 13.9 mill.
TYPE F:	14400 x 165	Tsh 2.4 mill.
Total investments in on-site disposal systems		Tsh 45.8 mill.

Investment phase 2:	Tsh 83.3 mill.

Phase 3: 1989 - 2009

The central sewerage system is expanded further, and more plots are connected. An eastern sewerage system is constructed in catchment area D (see fig. 6.2) which is draining to the same sewerage treatment ponds as the central sewerage system. Only residential areas are connected to the eastern sewerage system.

A few septic tanks TYPE E and F are provided in income group IV areas to replace old septic tanks.

Low-income areas in the western part of the town are provided with on-site disposal systems TYPE A, B or C.

In the eastern areas there are plots which will be connected to the sewerage system soon after year 2009. These areas will be provided with on-site disposal systems TYPE A, B or C to keep lost investments low.

Other plots situated far from the sewerage systems are provided with septic tanks TYPE E for income group III and IV areas and on-site disposal systems TYPE A, B or C for income group I and II areas.

Sewage and collected sludge is treated in sewage treatment ponds.

Operation and Maintenance·

Approximately 55,000 plots will have to be served by vacuum trucks, which means that 24 trucks will be required. Four labour teams run the sewage treatment plant, and six teams take care of sewer cleaning.

Total operation and maintenance cost. Tsh 8.900.000/year

Investment:

Available: Tsh 60.43 mill/year.

Investment size for phase 2:

(60.43 - 8.9) x 8.5136 = Tsh 438.7 mill.

The investments are utilized as follows (cf. table 9.1):

Central Sewerage system:

Sewage treatment and trunk sewers	Tsh 13.9 mill.
Main sewers	Tsh 16.0 mill.
Laterals	Tsh 50.0 mill.
Plot connections	Tsh 43.8 mill.
Total investments in central sewerage system	Tsh 123.7 mill.

Eastern Sewerage System:

The eastern sewerage system is similar to (but less extended than) the eastern sewerage system in alternative 1.

Sewage treatment and trunk sewers	Tsh 23.4 mill.
Main sewers	Tsh 16.7 mill.
Laterals	Tsh 21.8 mill.
Plot connections	Tsh 19.1 mill.
Total investments in eastern sewerage system	Tsh 81.0 mill.

On-Site Disposal Systems:

TYPE A:	2400 x 7587	Tsh 18.2 mill.
TYPE B:	3600 x 9891	Tsh 35.6 mill.
TYPE C:	5400 x 2638	Tsh 14.2 mill.
TYPE E:	7000 x 23612	Tsh 165.3 mill.
TYPE F	14400 x 50	Tsh 0.7 mill.
Total investments in on-site disposal systems		Tsh 234.0 mill.

Total investments phase 3:

Central sewerage system	Tsh 123.7 mill.
Eastern sewerage system	Tsh 81.0 mill.
On-site disposal systems	Tsh 234.0 mill.
Investments phase 3	Tsh 438.7 mill.

Main Advantages and Disadvantages

Advantages

Good control of effluent from industries, hospitals and high-density residential areas.

The combined system is very flexible, as investments can be shifted from on-site disposal systems to the sewerage system or vice versa depending on the development of the water supply system, available funds, development in building standard, etc. What is important, is the initiation of the construction of the sewerage system within phase 1.

This alternative includes the 'immediate action' sanitary programme, which benefits those being bad off in the field of sanitation. Thus good control and even a possible extermination of diarrhoeal diseases (cholera) is quickly provided.

This alternative implies, as compared to alternative 1, that the development of the sewerage system follows a more natural development of the water supply system and the building standard.

An attempt has been made to avoid, to the extent possible, investments in the expensive septic tanks (TYPE E and F) in areas sewered within few years after sanitary system provision, in order to minimize lost investments.

Throughout all the phases everybody is provided with practically the same level of protection against health hazards from faecal matter.

As more and more are connected to the sewerage system, the risk of groundwater and river pollution/contamination is reduced.

Disadvantages

The initial investment per plot for the sewerage-connected plots is very high: Tsh 29,412.

It appears, however, more reasonable to look at the average investment per plot for all three phases as a whole or at the average incremental cost as described in chapter 5. For the three phases the average investment in the sewerage system per connected plot is Tsh 13,400 which is an acceptable figure.

In this alternative foreign exchange will be required both for the sewerage system and vacuum trucks.

Tables and Figures

Table 9.1 shows for each phase the sanitation type provided in each residential area. Also the total number of types and sewerage connections are shown.

Table 9.2 shows the percentage provided with a sanitation unit or connected to the sewerage system for each income group in each phase. The corresponding investments are shown.

Tabel 9.2 is illustrated in fig. 9.1 where investments per plot are shown.

Fig. 9.2, 9.3 and 9.4 illustrate the sanitation types provided for each area in each phase and the development of the sewerage system.

Alternative 3

TABLE 9 1 DISTRIBUTION OF SANITATION SYSTEMS IN RESIDENTIAL AREAS

Area Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Income Group		IV	III	III	III	III	III	IV	I	II,III	II	I,II	II	III	II	III	IV	IV
Investment Period	Sanitation Type Provided																	
	Existing	349	503	96	87	236	611	576	587	84	506	721	502	15	448	175	170	205
	A		50			70	135		950	70		300	600		130	30		
Phase 1	B	215		80		50	110	200						5		15		
1979 -	C											240	100					
1984	D	200			100					60	200	590						
	E							286									68	35
	F																	67
	Sew Conn.	107	136	35	40					80	78							
Total Plots		871	689	211	227	356	856	1062	1537	294	784	1851	1202	20	578	220	238	307
	Existing	371	176	67	122	120	235	486	950	94	235	1130	700	5	130	45	229	297
	A		50				100		200						348	100		
Phase 2	B		50			65	100		387			151	302		100	75		
1984 -	C							465				100	200					
1989	D											100						
	E		57				140	165										5
	F							35									9	5
	Sew.Conn	500	356	144	105	171	281			200	549	370		15				
Total Plots		871	689	211	227	356	856	1151	1537	294	784	1851	1202	20	578	220	238	307
	Existing	607	492	179	145	171	281	1131	1537	280	627	1322	773	15	404	74	228	297
	A																	
Phase 3	B																	
1989 -	C																	
2009	E							10										
	F							10									10	10
	Sew.Conn.	264	197	32	82	185	575			14	157	1058	773	5	405	146		
Total Plots		871	689	211	227	356	856	1151	1537	294	784	2380	1546	20	809	220	238	307

Alternative 3

TABLE 9.1 DISTRIBUTION OF SANITARY SYSTEMS IN RESIDENTIAL AREAS (continued)

Area Number		18	19	20	48	49	50	52	53	55	57	60	61	Future Unnumbered Residential Areas				Total Sanitation Type
Income Group		IV	III	IV	III	I	I,II	II,III	IV	II	II	II	III	I	II	III	IV	
Investment Period	Sanitation Type Provided																	
	Existing	126	15	307														6319
	A		20		467			342										3164
Phase 1	B		19		206													900
1979 –	C																	340
1984	D																	1150
	E			35														424
	F	5		67														139
	Sew.Conn.																	476
Total Plots		131	54	409	673			342										12912
	Existing	125	39	394	673			342										6965
	A				173	900	1150	150										3171
Phase 2	B		20		200			163										1613
1984 –	C		18			911	1177											2871
1989	D																	100
	E			5					1616									1988
	F	6		10					100									165
	Sew.Conn.																	2691
Total Plots		131	77	409	1046	1811	2327	655	1716									19564
	Existing	121	67	399		1811	2327											13288
	A					217	1630					1540		4200				7587
Phase 3	B					200	800			295		1540	1000	4356	1700			9891
1989 –	C					100	835								1703			2638
	E		10										2009			9102	12481	23612
	F	10		10														50
	Sew.Conn.				1345			627	2402	2537	227	2951	1000					14982
Total Plots		131	77	409	1345	2328	5592	627	2402	2832	227	6031	4009	8556	3403	9102	12481	72048

Alternative 3

TABLE 9.2 DISTRIBUTION OF INVESTMENTS

Income Group		I		II		III		IV			
Investment Period	Sanitation Type Provided	% Provided of Total Plots	Investment Mill. Tsh	% Provided of Total Plots	Investment Mill. Tsh	% Provided of Total Plots	Investment Mill. Tsh	% Provided of Total Plots	Investment Mill Tsh	Total Provided	Total Investment Mill. Tsh
	A	9.7%	3.0	6 6%	2.0	8.2%	2.6				
Phase 1	B					3 8%	1 7	3 2%	1.5		
1979 -	C	1.9%	1.3	0.8%	0.5						
1984	D	4.6%	3.5	2 0%	1.6	0 8%	0.6	1 5%	1.2		
	E							3.3%	3 0		
	F							1 1%	2 0		
	Sew.Conn.			1.2%	4.6	1.7%	6.2	0 8%	3.2	3.7%	
Total		16.2%	7.8	10 6%	8.7	14 5%	11 1	9 9%	10.9	51 2%	38.5
	A	6.0%	2.8	6.0%	2.8	4 2%	1.9				
Phase 2	B	2 0%	1.4	2 8%	2 0	3.6%	2.5				
1984 -	C	6.9%	7 3	5.3%	5.6	0 1%	0.1	2 4%	2 5		
1989	D			0.5%	0.6						
	E					1 0%	1 4	9.2%	12 5		
	F							0 8%	2 4		
	Sew.Conn			4.7%	12 8	6 5%	17.7	2 6%	7 0	13 8%	
Total Sewerage Connections										16 2%	
Total		14 9%	11 5	19.3%	23.8	15 4%	23 6	15.0%	24 4	64 6%	83.3
Accumulated Total		25%	19 3	25%	32.5	25%	34.7	21 5%	35 3	96.5%	121 8
	A	8.5%	14 6	2.1%	3.7						
Phase 3	B	7.4%	19.3	4.9%	12.7	1 4%	3.6				
1989 -	C	1.3%	5.1	2.4%	9.2						
2009	E					15 4%	77.8	17 3%	87.5		
	F							0 1%	0.7		
	Sew.Conn			11 3%	110.8	5 8%	57.3	3 7%	36 4	20.8%	
Total Sewerage Connections										25 2%	
Total		17 2%	39.0	20.7%	136.4	22 6%	138.7	21 1%	124 6	81.6%	438.7
Accumulated Total		25%	58 3	25%	168 9	25%	173 4	24%	159.9	99%	560 5

FIG 91

ALTERNATIVE 3, SEWERAGE AND ON-SITE DISPOSAL SYSTEMS

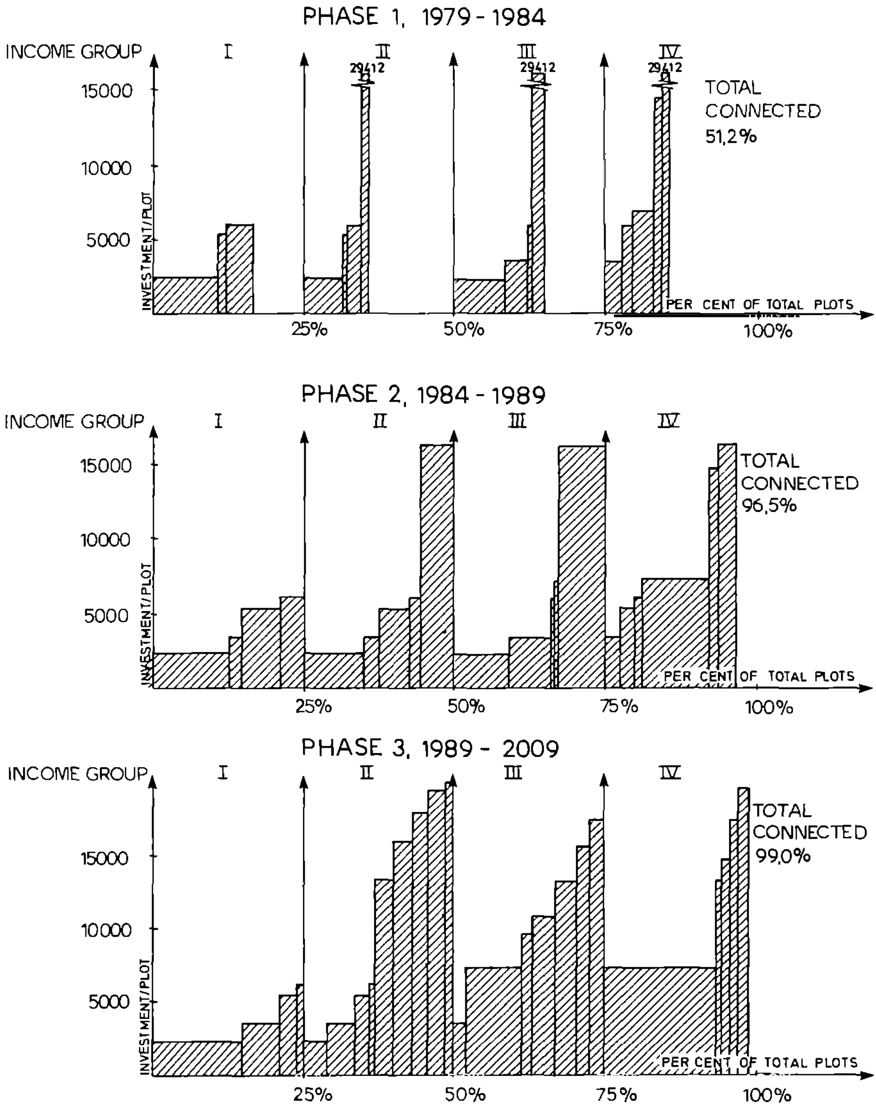


FIG 92

ALTERNATIVE 3, SEWERAGE AND ON-SITE DISPOSAL SYSTEMS
PHASE 1, 1979 - 1984

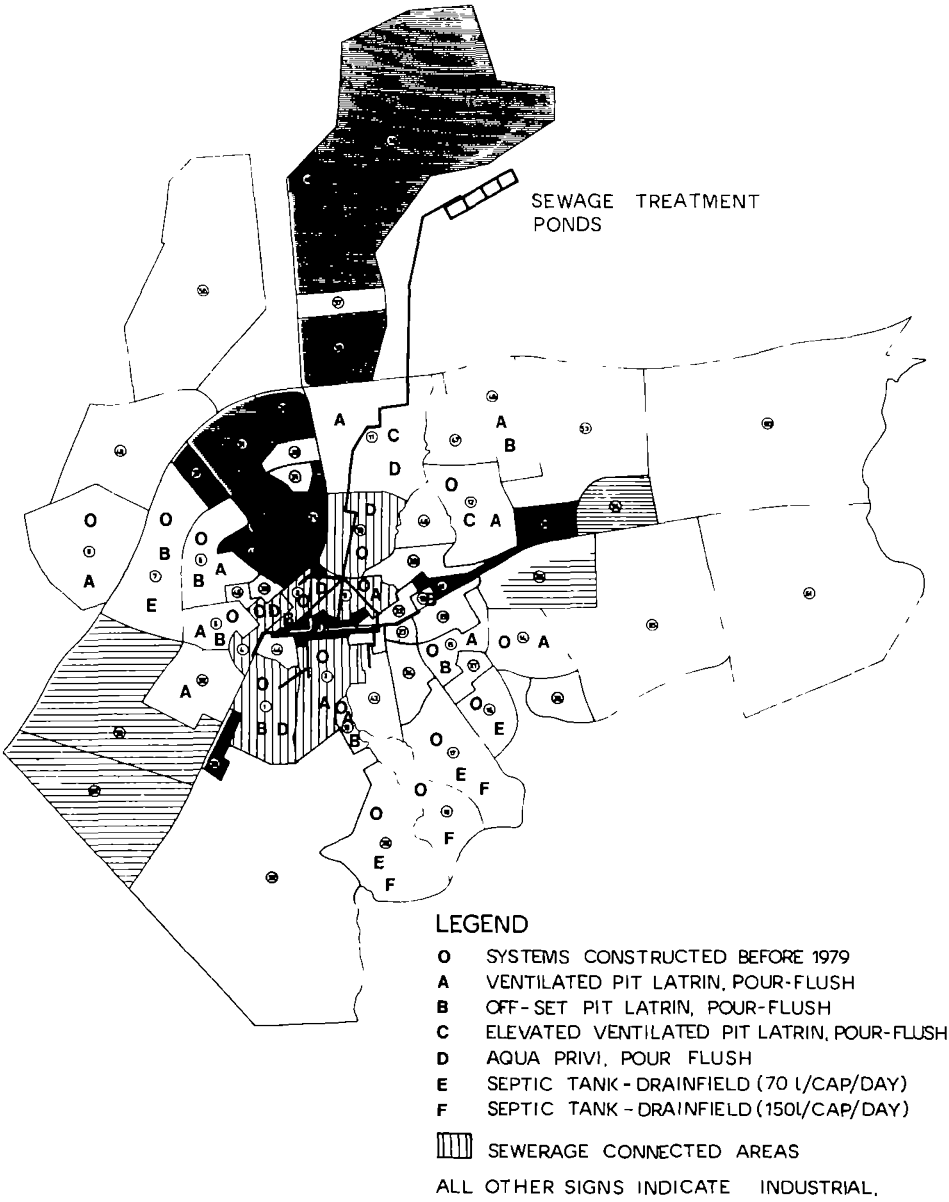
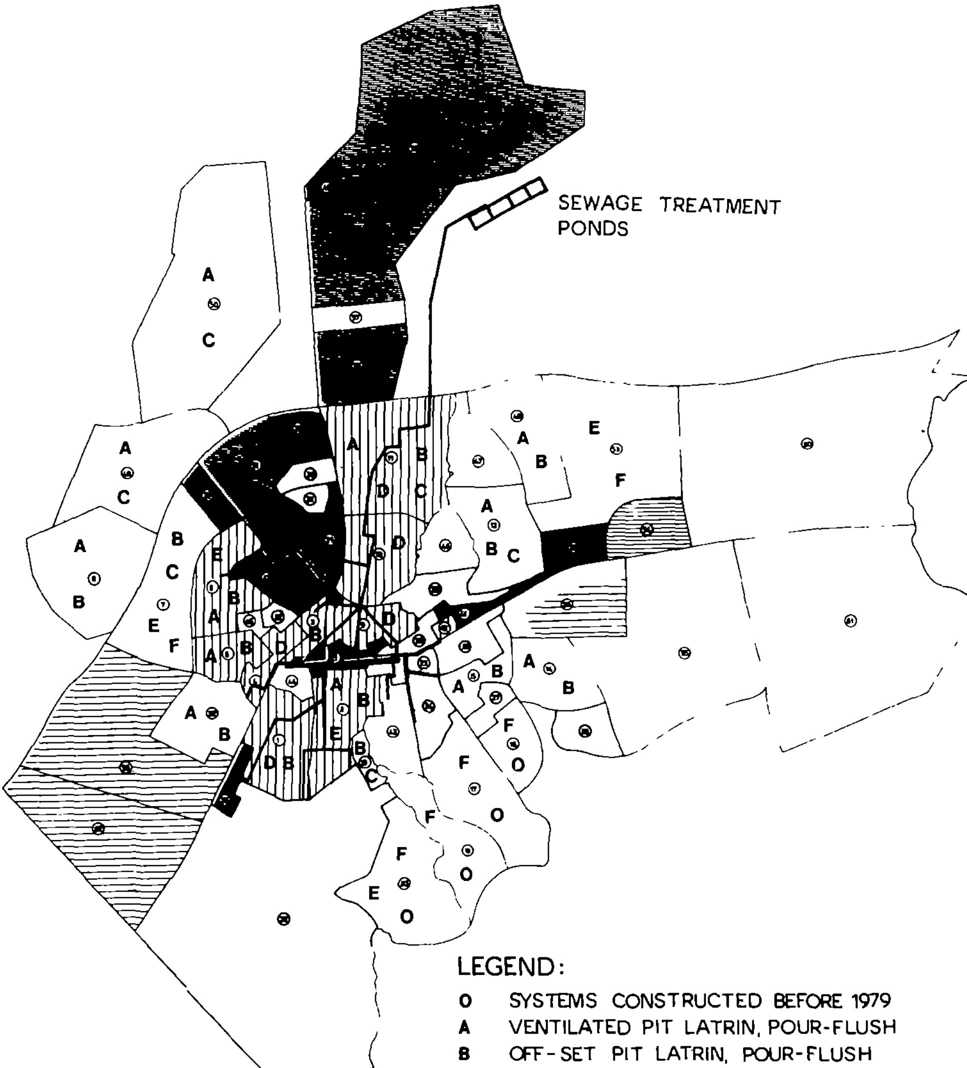


FIG. 93

ALTERNATIVE 3, SEWERAGE AND ON-SITE DISPOSAL SYSTEMS
PHASE 2, 1984 - 1989



LEGEND:

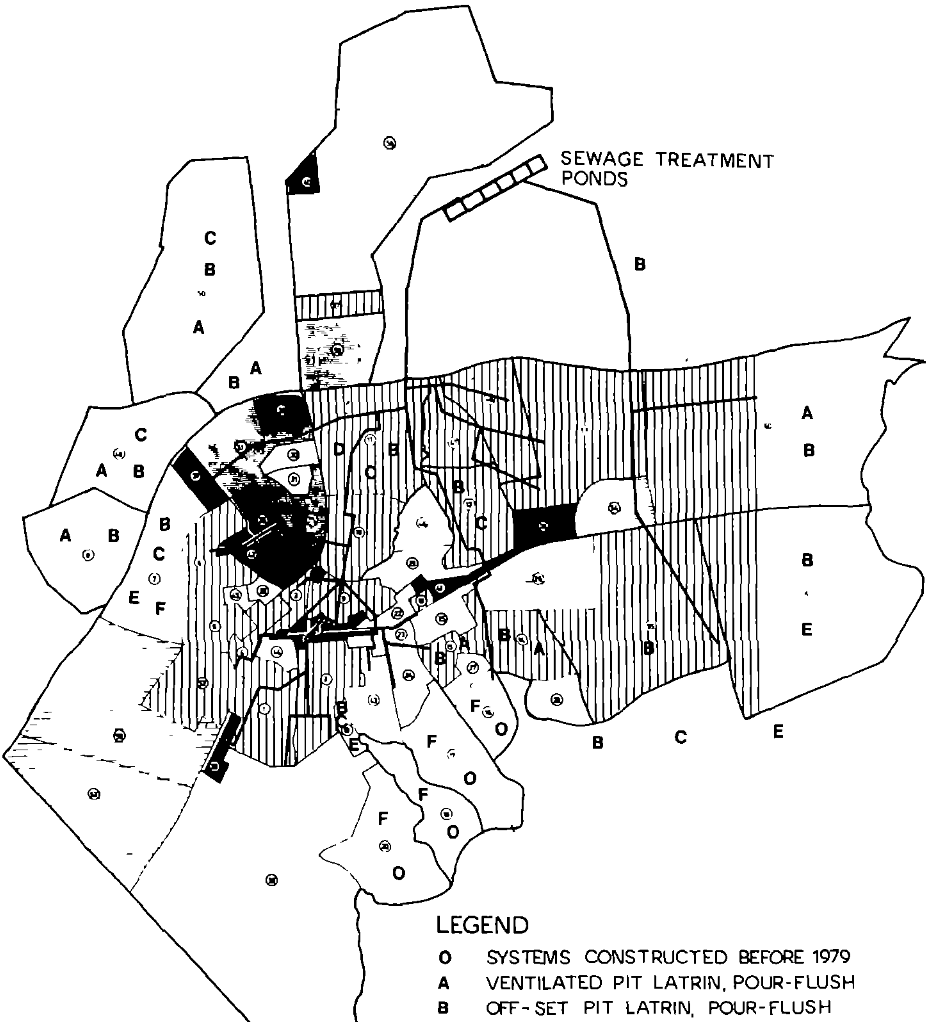
O SYSTEMS CONSTRUCTED BEFORE 1979
A VENTILATED PIT LATRIN, POUR-FLUSH
B OFF-SET PIT LATRIN, POUR-FLUSH
C ELEVATED VENTILATED PIT LATRIN, POUR-FLUSH
D AQUA PRIVI, POUR FLUSH
E SEPTIC TANK - DRAINFIELD (70 l/CAP/DAY)
F SEPTIC TANK - DRAINFIELD (150l/CAP/DAY)

SEWERAGE CONNECTED AREAS

ALL OTHER SIGNS INDICATE INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS

FIG 94

ALTERNATIVE 3, SEWERAGE AND ON-SITE DISPOSAL SYSTEMS
PHASE 3, 1989 - 2009



LEGEND

- O SYSTEMS CONSTRUCTED BEFORE 1979
- A VENTILATED PIT LATRIN, POUR-FLUSH
- B OFF-SET PIT LATRIN, POUR-FLUSH
- C ELEVATED VENTILATED PIT LATRIN, POUR-FLUSH
- D AQUA PRIVI, POUR FLUSH
- E SEPTIC TANK - DRAINFIELD (70 l/CAP/DAY)
- F SEPTIC TANK - DRAINFIELD (150l/CAP/DAY)
- SEWERAGE CONNECTED AREAS

ALL OTHER SIGNS INDICATE INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS

10. CASE STUDY, APPRAISAL

Technical Appraisal

The complicated ground condition is considered in all three alternatives.

Both the on-site disposal systems and the sewerage systems are generally little depending on any machinery or complicated mechanical parts. A pump station and mechanical aerators are installed in alternative 1 phase 3 but these technologies should be applicable within the next 20 years.

Wastewater discharge from industries, hospitals, schools etc. is well controlled in alternative 1 and 3.

The dependancy on vacuum trucks especially in alternative 2 for the whole urban area can give problems due to break downs of trucks, lack of spare-parts, lack of fuel-oil etc.

Alternative 1 applies a very heavy demand on the extension of the water supply system and development of building standard.

Alternative 3 provides the technical best solution.

Social Appraisal

All three alternatives are financed in relation to the users affordability!

Alternative 1 serves less than half the population although everybody is paying which could cause complications.

Alternative 2 and 3 serve the sanitary "badly off's" quickly and provide all with organised sanitary systems within the planning period.

The users habit of using water for anal cleansing is considered in all three alternatives.

Bucket latrines and communal toilets which are not preferred by the users are not provided.

In alternative 2 and 3 the user can contribute with own labour in building the superstructure for the on-site disposal systems. On the other hand he is not responsible for the parts important for the function of the system which is constructed on an organized basis.

Alternative 2 and 3 are both social acceptable.

Environmental Appraisal

Alternative 1 does not solve the sanitary problem for more than half the population and pollution of both receiving waters and the ground surface will be difficult to control.

The extensive soaking in alternative 2 could result in groundwater and possible river pollution, mainly with nitrogen compounds.

By not serving the slum areas the sanitation scheme proposed in alternative 1 does not control the outbreak of diarrhoeal diseases like cholera and typhoid.

Alternative 3 offers the best environmental protection.

Financial Appraisal

Using a discounting rate of 10% the average incremental cost at market price is calculated for each alternative. The detailed calculation is found in appendix G and the details for the calculations on the industrial, commercial and public areas are found in appendix G and E.

Unit: T sh /plot/year	Residential areas	Industrial, commercial and public areas	Total urban area
ALTERNATIVE 1	1,778	1,778	1,778
ALTERNATIVE 2	862	11,127	2,543
ALTERNATIVE 3	908	1,778	1,059

Table 10.1 Average Incremental Cost (AIC) at market price.

The AIC-values of table 10.1 must be compared to the average annually affordable instalments of T sh 839/plot.

Looking at the residential areas only, alternative 2 is a little more attractive than alternative 3 but when the total urban area is included alternative 3 is clearly the most attractive.

The operation and maintenance cost of the vacuum truck/vault system applied to industrial, commercial and public areas in alternative 2, is often underestimated. Rising oil prices will probably make this solution less attractive in the future. In this case the high operation and maintenance cost for industrial, commercial and public areas in alternative 2 makes this alternative financially unattractive.

Cash flow analysis of the alternatives is irrelevant considering the way of financing the sanitation schemes through affordable installments. Investments are made as the installments are collected through the municipal taxsystem.

Economic Appraisal

The cost of sanitation systems and operation and maintenance cost are shadow priced using the shadow factors indicated in appendix F. Appendix F also shows the detailed calculation of shadowed cost and Appendix G shows average incremental cost using shadow prices and a discounting rate of 10%.

Unit: T sh /plot/year	Residential areas	Industrial, commercial and public areas	Total urban area
ALTERNATIVE 1	2,465	2,465	2,465
ALTERNATIVE 2	1,117	17,433	3,790
ALTERNATIVE 3	1,219	2,465	1,436

Table 10.2 Average Incremental Cost (AIC) using shadow prices.

First of all it is seen that the calculations using shadowed prices show that the sanitary systems are more expensive to the economy than is revealed by the calculations using market prices. This is because all of the sanitary systems use a lot of imported materials.

Alternative 3 is also economically clearly the most cost effective when considering the total urban area.

11. CONCLUSION

The following conclusion is drawn from the case study and the field study, applying to sanitation schemes for urban areas with special reference to Africa.

The conclusion should be studied considering the conditions prevailing in Morogoro.

- the general complicated ground condition,
- the relative low average income level of $ 180/cap/year,
- a population density of 100-200 cap/ha which is rather typical for African urban areas,
- the poor service level of existing sanitation and water supply
- and the users preferences, habits and desire to improve their well-being.

1. Taking into account that a minimum service level must be kept for all, it is possible to finance a sanitation scheme to the benefit of everybody within 5-10 years using only affordable instalments. It is proposed that these instalments are based on the following proportions of the household income:

   o low and low middle income groups 2%
   o middle income group 3%
   o high income group 4%

   These instalments should be collected from all as a special levy e.g. through the municipal tax system. The fee paid for provision of a sanitary system is thus not directly related to the services provided.

2. Support is given to the approach that the annual investments in sanitation schemes proposed in wastewater master plans should be directly related to household incomes contrary to present common practice.

3. Alternative projects should be compared and appraised catering for a wide range of socio-economic, cultural and technical aspects, rather than being compared from the aspect of their total cost only.

   Benefits should be assessed not in monetary terms (which is impossible) but e.g. in number of connections to a sanitary system. The average incremental approach should be applied to compare and appraise benefits accrued.

4. Sanitation schemes can only be appraised when considering the whole complex urban area including industries, hospitals, shools etc.

5. Water supply and sanitation must be considered simultaneously in development projects. If the water supply system is extended and no sanitation is provided sullage control could become a major problem. On the contrary is a house-connected water supply at a service level of 80-100 l/cap/day necessary for the well-functioning of a sewerage system.

6. The question of appropriate initiation of a sewerage system concerning potential connectors can be appraised in using the average incremental cost (AIC) approach.

7. Sewerage systems typically provide the most feasible method of controlling industrial and hospital wastewater discharge.

8. On-site disposal systems provide the desired minimum service level if they are well designed and well constructed. This can be assured if on-site disposal systems are included in sanitation schemes and the provision thus is a government (or municipal) responsibility.

9. When applying both sewerage systems and on-site disposal systems to a sanitation scheme it is possible to propose a scheme catering for all based on the community's financial capability. The provision of a sanitary system is thus not a question of sewerage system or nothing but a question of finding the appropriate combination of sewerage system and on-site disposal systems.

10. Operation and maintenance should be given a high priority in future sanitation schemes. This implies making funds available for this and the training of labour teams. Also it is of vital importance to establish an organisation responsible for operation and maintenance.

11. The objective of a sanitation project should be clearly defined. It should not be the provision of a sewerage system for the purpose of having such one. The objective will typically be to prevent the spread of water and excreta related diseases, to reduce infant mortality rates and to improve the environment.

APPENDICES

APPENDIX A

LIST OF REFERENCES

/1/ Sewerage and Low Cost Sanitation for Marogoro Town, Preliminary Design, Cowiconsult,sep. 1979.

/2/ National Sites and Services Project Phase III, Morogoro, Min. Lands ect. Tanzania, 1979.

/3/ Housing, Sector policy paper, World Bank 1975.

/4/ Ismalia Demonstration Projects, ODM ect., 1978.

/5/ The Future Planning of A Majengo, Housing Research ect., Nairobi 1976.

/6/ Appropriate Sanitation Alternatives: A Field Manual, World Bank, 1978.

/7/ Water, Waste and Health in Hot Climates, Feachem et. al., 1977.

/8/ Appropriate Sanitation Alternatives: A Technical and Economical Appraisal, World Bank, 1978.

/9/ Alternative Sanitation Technologies for Urban Areas in Africa, World Bank, 1979.

/10/ Site and Service Strategy Assessed,"Build"- Kenya, 1979.

APPENDIX B

GLOSSARY OF TERMS

Economic Terms

Appraisal
The examination of a project before ("ex ante") the project is undertaken. (See also Evaluation, below).

Discount Rate
The opportunity cost of capital in its next best alternative use: the rate by which the project's annual costs and benefits are discounted to produce the project's Net Present Value.

Evaluation
The examination of a project after ("ex post") the project has been undertaken. (See also Appraisal, above).

Market Price
The price of a good or service bought on the open market.

Net Present Value (NPV)
The present sum of money which is equivalent to all future flows or money discounted at a rate of interest.

Opportunity Cost
The value to society of a good or service in its best alternative use.

Shadow Price
The social value of a good or service; the opportunity cost of a good or service.
T sh = Tanzanian Shilling

Engineering Terms

Anaerobic Pond
Ponds which are devoid of dissolved oxygen. Settled solids and sludge from vacuum trucks are digested anaerobically.

Compost
The humus-like product of the aerobic and anaerobic composting of night soil or sludge (may have organic matter added to it)

Effluent
The liquid outflow from a sewage treatment works, septic tank or aqua privy.

Excreta
Faeces and urine of human origin.

Helminth
Parasitic Worm.

Pathogen
An organism which causes disease; normally microscopic in size.

Sanitation
The collection, treatment and disposal of domestic and industrial wastewater and night soil.

Septage
The accumulated scum and sludge in septic tanks and wet pits.

Sewerage
A system of pipes and appurtenances for the collection and transportation of waterborne domestic and industrial wastes.

Sewage
Human Excreta diluted by water.

Sludge
The dense fraction which settles out by gravity when sewage stands for any length of time in the treatment process e.g. septic tank, primary sedimentation.

Sullage
Domestic waste water not containing excreta e.g. bath water or laundry water. Also called grey water (American practice).

Wastewater
The water-borne wastes of a community.

APPENDIX C

WASTEWATER FLOWS TO SANITATION SYSTEMS

For sewerage connected houses wastewater flows are taken from Cowiconsult /1/.

Sanitation System	Phase 1 m^3/plot/day	Phase 2 m^3/plot/day	Phase 3 m^3/plot/day
Sewerage	0.8	0.9	1.3
Septic tank, Type F	0.8	0.9	1.3
Septic tank, Type E	0.7	0.8	0.9
On-site, Type D	0.4	0.6	0.7
On-site, Type C	0.2	0.3	0.3
On-site, Type B	0.2	0.3	0.3
On-site, Type A	0.2	0.3	0.3

Wastewater flows from industrial, commercial and public areas are taken from Cowiconsult /1/.

TOTAL WASTEWATER FLOW TO THE SEWERAGE SYSTEM (ALT. 1 AND ALT. 3)
WASTEWATER FROM INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS TO VAULTS (ALT. 2)

ALTERNATIVE 1

	Phase 1 m^3/d	Phase 2 m^3/d	Phase 3 m^3/d
Residential areas	1,830	8,403	43,509
Industrial, commercial and public areas	784	3,602	18,647
Total	2,614	12,005	62,156

ALTERNATIVE 2

	Phase 1 m^3/d	Phase 2 m^3/d	Phase 3 m^3/d
Industrial, commercial and public areas	784	3,602	18,647

ALTERNATIVE 3

	Phase 1 m^3/d	Phase 2 m^3/d	Phase 3 m^3/d
Residential areas	377	2.850	23.521
Industrial, commercial and public areas	784	3,602	18,647
Total	1,161	6,452	42,168

GENERAL DESIGN CRITERIA

Ponds

The anaerobic ponds are designed for a load of 15 m^3 per truck per day 30 days retention i.e. 450 m^3 per truck.

The sewage treatment pond is designed for 30 days hydraulic retention time.

Sewers

Minimum diameter: Laterals 160 mm
Mains 225 mm

Main sewers designed to maximum 2/3 full.

PVC-piping for diametres up to 400 mm
Concrete piping for diametres above 400 mm.

Hydraulic Design

The hydraulic design of PVC sewer pipes is based upon Colebrook and White's formulae:

$$V = \left[\frac{2g}{f}\right]^{\frac{1}{2}} x R^{\frac{1}{2}} x I^{\frac{1}{2}}$$

where f is derived from the formulae:

$$\left[\frac{2}{f}\right]^{\frac{1}{2}} = 6.4 - 2.45 \ln \left[\frac{k}{R} + \frac{4.7}{Re\ (f)^{\frac{1}{2}}}\right]$$

Re: is Reynolds figure

k: coefficient of roughness

V: flow/cross sectional area of flowing stream of water (velocity m/sec)

R: hydraulic radius (m)

I: slope (m/m)

The hydraulic design of concrete pipes is based on the conventional Manning formulae:

$$V = \frac{1}{n} x R^{\frac{2}{3}} x I^{\frac{1}{2}}$$

n: coefficient of roughness

n: 0.015 for dia. 450 - 500 mm

n: 0.013 for dia. 600 - 1050 mm

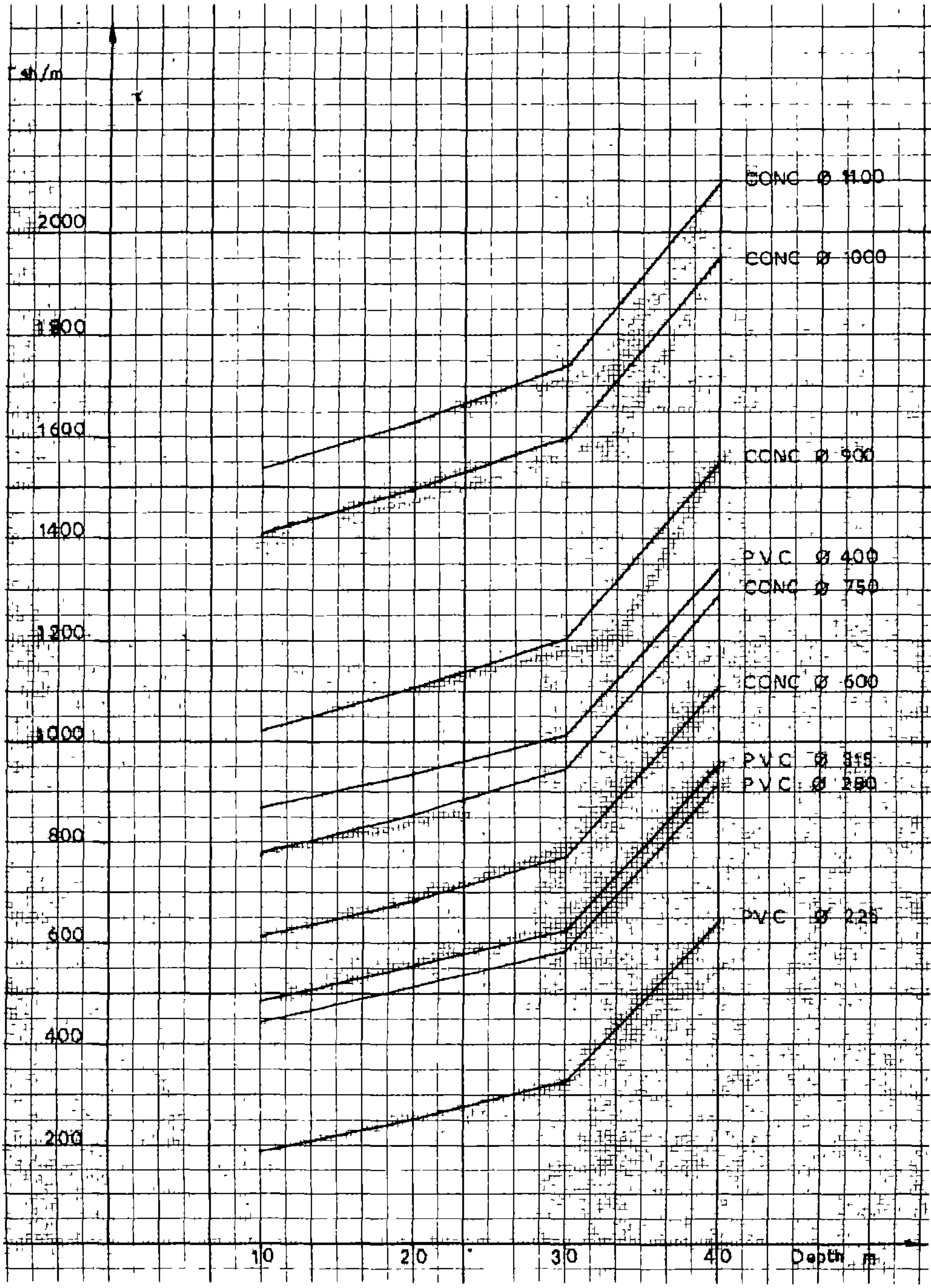
Minimum slopes:	Min. slope
From plot to lateral manhole:	1%
Line serving up to 6 houses:	0.8%
Line serving more than 6 houses:	0.5%
Trunk sewers:	0.2%

APPENDIX E

UNIT PRICES FOR COST ESTIMATE (Price level 1979)

Description of Works			Units	Cost per unit
1. Excavation	(i)	Bulk	m^3	T.shs. 45.00
	(ii)	Trenches Depth > 2.o	m^3	T.shs. 30.00
	(iii)	Trenches Depth > 2.o < 3.o	m^3	T.shs. 35.00
	(iv)	Trenches Depth > 3.o	m^3	T.shs. 40.00
2. Concrete	(i)	Mass concrete placed	m^3	T.shs. 900.00
	(ii)	Reinforced concrete incl. shuttering, reinforced steel placing and compaction	m^3	T.shs. 1,500.00
3. Manholes	(i)	Type A, small blockwalls (15o mm) Depth < 2.o m	Unit	T.shs. 1,900.00
	(ii)	Type B, blockwalls 225 mm Depth < 2.o m	Unit	T.shs. 2,800.00
	(iii)	Type C, concrete rings		
		a) Depth 2.o m	Unit	T.shs. 3,000.00
		b) Depth 3.o m	Unit	T.shs. 4,000.00
		c) Depth 4.o m	Unit	T.shs. 5,000.00
	(iv)	Type D, reinforced concrete Depth < 2.o m	Unit	T.shs. 5,000.00
4. On-Site Disposal Systems (Sub Structure)				
	(i)	Ventilated pit latrines	Unit	T.shs. 1,500.00
	(ii)	Elevated ventilated pit latrines	Unit	T.shs. 4,000.00
	(iii)	Aqua Privy	Unit	T.shs. 4,500.00
	(iv)	Septic Tanks - Drainfield	Unit	T.shs. 12,000.00
5. On-Site Disposal Systems (Superstructure)			Unit	T.shs. 2,500.00
6. Communal Latrines (4 stalls)				
	(i)	Aqua Privy Communal Latrines	Unit	T.shs. 17,000.00
	(ii)	Sewer Communal Latrines	Unit	T.shs. 13,000.00
6. Plot Installation			Plot	T.shs. 3,500.00
7. Laterals			Plot	T.shs. 4,000.00

Unit Prices for Construction of Sewers (Price level 1979)



COST OF THE VACUUM TRUCK / VAULTS SYSTEM FOR INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS

ALTERNATIVE 2

One plot equivalent = 9 person equivalent
cost of vault per plot equivalent Tsh 8,750
Operation and maintenance per plot equivalent Tsh 10,000 / year.

Shadow factor for vault as for septic tank : 1.29
Shadow cost for vault Tsh 11,290.

OPERATION AND MAINTENANCE

Septage management

For emptying wet pit, aqua privies and septic tanks, vacuum trucks are used. Assuming that sludge has to be collected once every fifth year on average from each plot and one vacuum truck can empty 3 pits or tanks a day working 7 hours a day. Further they are operating 150 days a year. One truck can then serve: 3 x 150 x 5 = 2,250 plots

Cost:
The annual cost of running a truck is:

Writing off (Capital cost T Sh 600.000, 6 years life)	:	T Sh	100,000
Interest (average 10% p.a.)	:	T Sh	60,000
Fuel (100 l/d)	:	T Sh	60,000
Repair	:	T Sh	60,000
Running cost	:	T Sh	280,000/year

For each truck there is one foreman and 2 labourers
Annual cost fo labour per truck:

1 Foreman	:	T Sh	25,000
2 Labourers	:	T Sh	20,000
Labour cost	:	T Sh	45,000/year

Total running cost per truck	:	T Sh	325,000/year

Sewer Cleaning

Anaerobic ponds and sewerage treatment ponds require operation and maintenance teams consisting of one foreman and 5 labourers. Further they use some materials, equipment and a pick-up for transport.

The oxidation ditch plant requires 2 foremen, 10 labourers, some materials and equipment and transport.

The need for materials, equipment and transport is assumed for each phase in an alternative.

APPENDIX F

SHADOW COSTING

Opportunity cost of capital or discounting rate 10 %
skilled labour earns 2.5 x unskilled labour and the ratio of skilled to unskilled labour is 1:4.

Shadow factor used

Unskilled labour	(abundant in Morogoro)	0.7
Skilled labour	(in short supply)	1.5
Foreign exchange	(see World Bank /8/)	1.5
Local materials	(see World Bank /8/)	1.0
Fuel oil - transport	(unstable (even scarce) commodity)	4.0

Shadow cost estimates for sanitation units

TYPE A, Pit latrin

	Market cost Tsh	Shadow factor	Shadow cost Tsh
Imported material	1200	1.5	1800
Local material	100	1.0	100
Labour	700	0.86	602
	2000		2502
+ 20% Contingencies	2400		3000

TYPE B, Off - set pit latrin

	Market cost Tsh	Shadow factor	Shadow cost Tsh
Imported materials	1700	1.5	2550
Local materials	300	1.0	300
Labour	1000	0.86	860
	3000		3710
+ 20% contingencies	3600		4450

TYPE C, Elevated improved pit latrin

	Market cost Tsh	Shadow factor	Shadow cost Tsh
Imported materials	2600	1.5	3900
Local materials	500	1.0	500
Labour	1400	0.86	1204
	4500		5604
+ 20% contingecies	5400		6725

TYPE D, Aqua privy

	Market cost Tsh	Shadow factor	Shadow cost Tsh
Imported materials	3000	1.5	4650
Local materials	500	1.0	500
Labour	1400	0.86	1204
	4900		6354
+ 20% Contingencies	5900		7625

TYPE E, Small septic tank

	Market cost Tsh	Shadow factor	Shadow cost Tsh
Imported materials	3800	1.5	5700
Local materials	500	1.0	500
Labour	1500	o.86	1290
	5800		7490
+ 20% Contingencies	7000		9000

TYPE F, septic tank

	Market cost Tsh	Shadow factor	Shadow cost Tsh
Imported materials	8000	1.5	12000
Local materials	1000	1.0	1000
Labour	3000	0.86	2580
	12000		15580
+ 20% Contingencies	14400		18700

Sewerage system

General shadow factor

	Weight	Shadow factor	Shadowed weight
Imported materials	10	1.5	15
Local materials	1	1.0	1
Labour	2	0.86	1.72
	13		17.72

shadow factor 17.72 / 13 = 1.36

Sewer pipes are assumed locally manufactured using imported machinery and equipment. Cement and steelbars are also imported.

Shadow cost estimates for operation and maintenance

General shadow factor

	Weight	Shadow factor	Shadow weight
Imported materials	18	1.5	27
Fuel oil	3	4.0	12
Local materials	1	1.0	1
Labour	6	0.86	5.2
	28		45.2

shadow factor 45.2 / 28 = 1.6

APPENDIX G

AVERAGE INCREMENTAL COST AT MARKET PRICE

	Residential areas			Industrial, commercial and public areas			Total urban area		
	C.I.	O.+M.	P.C.	C.I.	O.+ M.	P.C.	C.I.	O.+ M.	P.C.
ALT. 1									
Phase 1	38.0	0.95	2,310	16.3	0.41	990	54.3	1.36	3,300
Phase 2	86.6	1.77	9,334	37.1	0.76	4,002	123.7	2.53	13,336
Phase 3	465.6	5.74	33,572	199.5	2.46	14,388	665.1	8.20	47,960
Present value	137.7	17.2	87,118	59.0	7.4	37,342	196.7	24.6	124.460
AIC		1,778			1,778			1,778	
ALT. 2									
Phase 1	38.5	0.90	8,315	8.7	9.90	990	47.2	10.8	9,305
Phase 2	81.2	2.35	18,508	35.0	40.02	4,002	116.2	42.37	22,510
Phase 3	420.8	11.00	71,400	125.9	143.88	14,388	546.7	154.88	85,788
Present value	138.1	26.3	190,626	44.5	371.0	37,342	182.6	397.3	227,968
AIC		862			11,127			2,543	
ALT. 3									
Phase 1	38.5	0.90	6,611	16.3	0.41	990	54.8	1.31	7,601
Phase 2	83.3	2.10	18,879	37.1	0.76	4,002	120.4	2.86	22,881
Phase 3	438.7	8.90	71,328	199.5	2.46	14,388	638.2	11.36	85,716
Present value	137.7	22.6	176,692	59.0	7.4	37,336	196.7	30.0	214,028
AIC		908			1,778			1,059	

C.I. = Capital investments in mill. T Sh

O + M = Operation and maintenance in mill. T Sh

P.C. = Plots connected

AIC = Average incremental cost in T Sh /plot/year

AVERAGE INCREMENTAL COST AT SHADOW PRICE

	Residential areas			Industrial, commercial and public areas			Total urban area		
	C.I	O.+M.	P.C.	C.I.	O.+ M.	P.C.	C.I.	O.+ M.	P.C.
ALT. 1									
Phase 1	51.7	1.52	2,310	22.2	0.66	990	73.9	2.18	3,300
Phase 2	117.8	2.83	9,334	50.5	1.22	4,002	168.3	4.05	13,336
Phase 3	633.2	9.18	33,572	271.3	3.94	14,388	904.5	13.12	47,960
Present value	187.3	27.5	87,118	80.2	11.8	37,342	267.5	39.3	124,460
AIC		2,465			2,465			2,465	
ALT. 2									
Phase 1	48.8	1.44	8,315	11.2	15.84	990	60.0	17.28	9,305
Phase 2	104.5	3.76	18,508	45.2	64.03	4,002	149.7	67.79	22,510
Phase 3	541.5	17.60	71,400	162.4	230.21	14,388	703.9	247.81	85,788
Present value	177.1	35.8	190,626	57.4	593.6	37,342	234.5	629.4	227,968
AIC		1,117			7,433			3.790	
ALT. 3									
Phase 1	50.0	1.44	6,611	22.2	0.66	990	72.2	2.10	7,601
Phase 2	108.7	3.36	18,879	50.5	1.22	4,002	159.2	4.58	22,881
Phase 3	573.4	14.24	71,328	271.3	3.94	14,388	844.7	18.18	85,716
Present value	179.2	36.2	176,692	80,2	11.8	37,342	259.4	48.0	214,034
AIC		1,219			2,465			1,436	

C.I. = Capital investments in mill. T Sh

O.+ M. = Operation and maintenance in mill. T Sh

P.C. = Plots connected

AIC = Average incremental cost in T Sh /plot/year.

ALTERNATIVE 1

Average Incremental Cost (AIC)
(Constant base year market prices, 1979)

Year	Capital investments	Operation and Maintenance	Plots connected
	Mill. T Sh	Mill. T Sh	
1		0	0
2		0.24	578
3	38.0 (years 1–5)	0.48	1,155
4		0.71	1,733
5		0.95	2,310
6		1.11	3,715
7		1.28	5,120
8	86.6 (years 6–10)	1.44	6,524
9		1.61	7,929
10		1.77	9,334
11		1.97	10,546
12		2.17	11,758
13		2.37	12,970
14		2.56	14,182
15		2.76	15,394
16		2.96	16,606
17		3.16	17,818
18		3.35	19,030
19		3.56	20,242
20		3.76	21,454
21		3.95	22,666
22	465.6 (years 11–30)	4.15	23,878
23		4.35	25,040
24		4.55	26,302
25		4.74	27,514
26		4.95	28,726
27		5.14	29,938
28		5.34	31,150
29		5.54	32,361
30		5.74	33,572
Scrap value	399.0		
Present Values	137.74	17.2	87,118

Capital investments evenly distributed for each phase.

Linear growth of Operation and Maintenance cost for each phase.

Sewerage systems: 40 years life

$$AIC = \frac{137.74 + 17.2}{87,118} \times 10^6 = \text{T Sh } 1,779/\text{plot/year}$$

$$= \underline{\text{US\$ } 217/\text{plot/year}}$$

ALTERNATIVE 2

Average Incremental Cost (AIC)
(Constant base year market prices, 1979)
Residential Areas.

Year	Capital investments Mill. T Sh	Operation and Maintenance Mill. T Sh	Plots connected
1		0	0
2		0.23	2,084
3	38.5	0.45	4,167
4		0.68	6,251
5		0.90	8,334
6		1.19	10,369
7		1.48	12,404
8	81.2	1.77	14,438
9		2.06	16,473
10		2.35	18,508
11		2.78	21,153
12		3.22	23,797
13		3.65	26,442
14		4.08	29,086
15		4.51	31,731
16		4.95	34,376
17		5.38	37,020
18		5.81	39,665
19		6.24	42,309
20		6.68	44,954
21		7.11	47,599
22	420.8	7.54	50,243
23		7.97	52,888
24		8.41	55,532
25		8.84	58,177
26		9.27	60,822
27		9.70	63,466
28		10.14	66,111
29		10.57	68,755
30		11.00	71,400
Scrap value	-210.4		
Present Values	138.06	26.3	190,626

Capital investments evenly distributed for each phase.
Linear growth of Operation and Maintenance cost for each phase.
On-site disposal systems: 20 years life

$$AIC = \frac{138.06 + 26.3}{190,626} \times 10^6 = \text{T Sh } 862/\text{plot/year}$$

$$= \text{US\$ } 105/\text{plot/year}$$

ALTERNATIVE 2

Average Incremental Cost

(Constant base year market prices, 1979)

Including industrial, commercial and public areas.

Present values for industrial, commercial and public areas:

One p.e. is the per capita discharge per day

One plot-equivalent is 9 p.e.

Cost of vacuum truck cartage per plot-equivalent:

Investment cost: T.Sh. 8,750, Operational and Maintenance: T.Sh. 10,000/year

Year	Capital investments Mill. T Sh	Operation and Maintenance Mill. T Sh	Plots connected
1		0	0
2		3.23	248
3	8.66	4.84	495
4		8.07	743
5		9.68	990
6		16.13	1,592
7		22.58	2,195
8	35.02	27.42	2,797
9		33.87	3,400
10		40.33	4,002
11		45.16	4,521
12		50.00	5,041
13		56.46	5,560
14		61.29	6,079
15		66.13	6,594
16		70.97	7,118
17		75.81	7,637
18		82.26	8,156
19		87.10	8,676
20	125.90	91.94	9,195
21		96.78	9,714
22		101.62	10,234
23		108.07	10,753
24		112.91	11,272
25		117.75	11,792
26		122.59	12,311
27		127.43	12,830
28		133.88	13,349
29		138.72	13,869
30		143.56	14,388
Scrap value	-62.95		
Present Values	44.47	370.97	37,342

Capital investments evenly distributed for each phase.

Linear growth of Operation and Maintenance cost for each phase.

On-site disposal systems: 20 years life.

For present values of residential areas see appendix

$$AIC = \frac{138.06 + 26.3 + 44.47 + 370.97}{37,342 \quad + 190,626} \times 10^6 = \text{T Sh} \quad 2,543.3/\text{plot/year}$$

$$= \underline{\text{US\$} \quad 310.2/\text{plot/year}}$$

ALTERNATIVE 3

Average Incremental Cost (AIC)

(Constant base year market prices, 1979)

Including industrial, commercial and public areas.

Investments, Operation and Maintenance Cost and Plot equivalent connected is found using the flow distribution appendix C.

Year	Capital investments Mill. T Sh	Operation and Maintenance Mill. T Sh	Plots connected
1		0	0
2		0.3	1,896
3	81.6	0.61	3,792
4		0.91	5,688
5		1.21	7,583
6		1.51	9,394
7		1.82	11,206
8	130.64	2.12	13,017
9		2.43	14,829
10		2.73	16,640
11		3.16	20,094
12		3.59	23.548
13		4.01	27,002
14		4.44	30,455
15		4.82	33,910
16		5.30	37,363
17		5.72	40,817
18		6.15	44,270
19		6.58	47,725
20		7.01	51,178
21		7.43	54,632
22		7.86	58,086
23		8.29	61,540
24	600.85	8.72	64,993
25		9.14	68,448
26		9.57	71,901
27		10.00	75,355
28		10.43	78,808
29		10.85	82,263
30		11.28	85,716
Scrap value	-447.67		
Present Values	218.81	29.1	214,034

Capital investments evenly distributed for each phase.

Linear growth of Operation and Maintenance cost for each phase.

On-site disposal systems: 20 years life

Sewerage system: 40 years life

$$AIC = \frac{218.81 + 29.1}{214,034} \times 10^6 = \text{T Sh } 1,158/\text{Plot/Year}$$

$$= \underline{\text{US\$ } 141/\text{Plot/Year}}$$

ALTERNATIVE 3

Average Incremental Cost (AIC)

(Constant base year market prices, 1979)

Residential areas

Year	Capital investments Mill. T Sh	Operation and Maintenance Mill. T Sh	Plots connected
1		0	0
2		0.23	1,648
3		0.45	3,297
4	38.5	0.68	4,945
5		0.90	6,593
6		1.14	7,802
7		1.38	9.011
8	83.3	1.62	10,220
9		1.86	11,429
10		2.10	12,638
11		2.44	15,573
12		2.78	18,507
13		3.12	21,442
14		3.46	24,376
15		3.80	27,311
16		4.14	30,245
17		4.48	33,180
18		4.82	36,114
19		5.16	39,049
20		5.50	41,983
21		5.84	44,918
22	438.7	6.18	47,852
23		6.52	50,787
24		6.86	53,721
25		7.20	56,656
26		7.54	59,590
27		7.88	62,525
28		8.22	65,459
29		8.56	68,394
30		8.90	71,328
Scrap value	-291.3		
Present Values	137.74	22.6	176,692

Capital investments evenly distributed for each phase.

Linear growth of Operation and Maintenance cost for each phase.

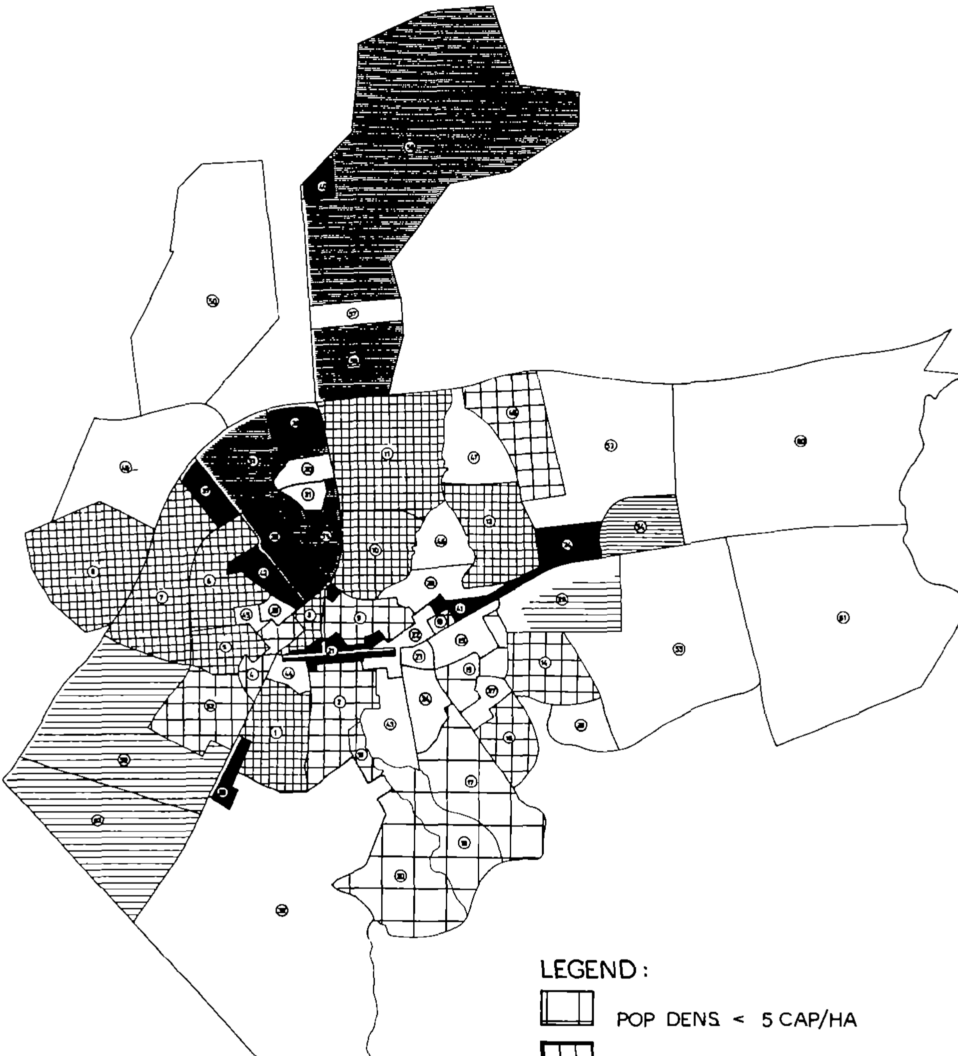
On-site disposal systems: 20 years life

Sewerage system: 40 years life

$$AIC = \frac{137.74 + 22.6}{176,692} \times 10^6 = \text{T.Sh. 908/plot/year}$$

$$= \underline{\text{US\$ 111/plot/year}}$$

FIG. 121
POPULATION DENSITIES 1984
(RESIDENTIAL AREAS ONLY)



LEGEND:

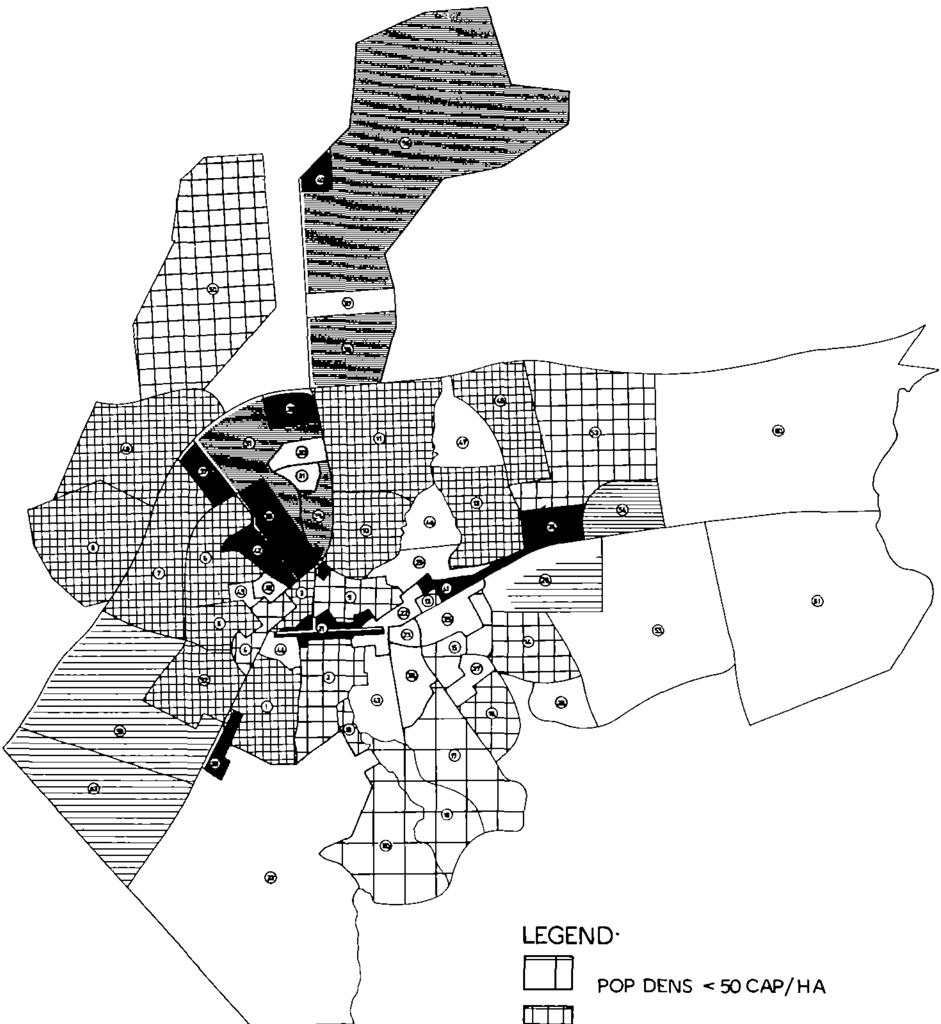
POP DENS < 5 CAP/HA

50 CAP/HA ≤ POP DENS ≤ 100 CAP/HA

POP DENS > 100 CAP/HA

ALL OTHER SIGNS INDICATE INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS

FIG 12 2
POPULATION DENSITIES 1989
(RESIDENTIAL AREAS ONLY)



LEGEND·

POP DENS < 50 CAP/HA

50 CAP/HA ≤ POP. DENS ≤ 100 CAP/HA

POP DENS > 100 CAP/HA

ALL OTHER SIGNS INDICATE
INDUSTRIAL, COMMERCIAL AND
PUBLIC AREAS

FIG 12.3
POPULATION DENSITIES 2009
(RESIDENTIAL AREAS ONLY)

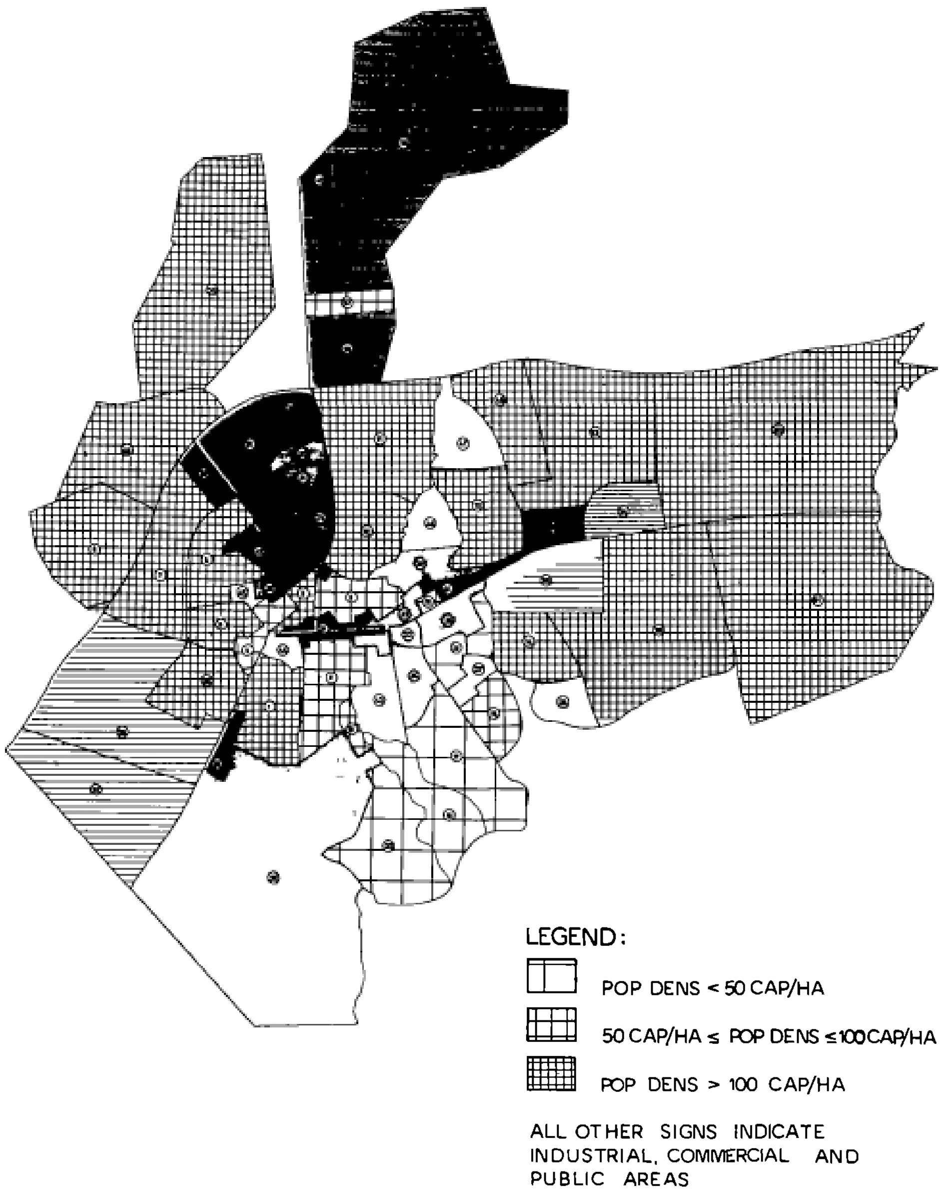


FIG. 12.4
INCOME DISTRIBUTION 1984

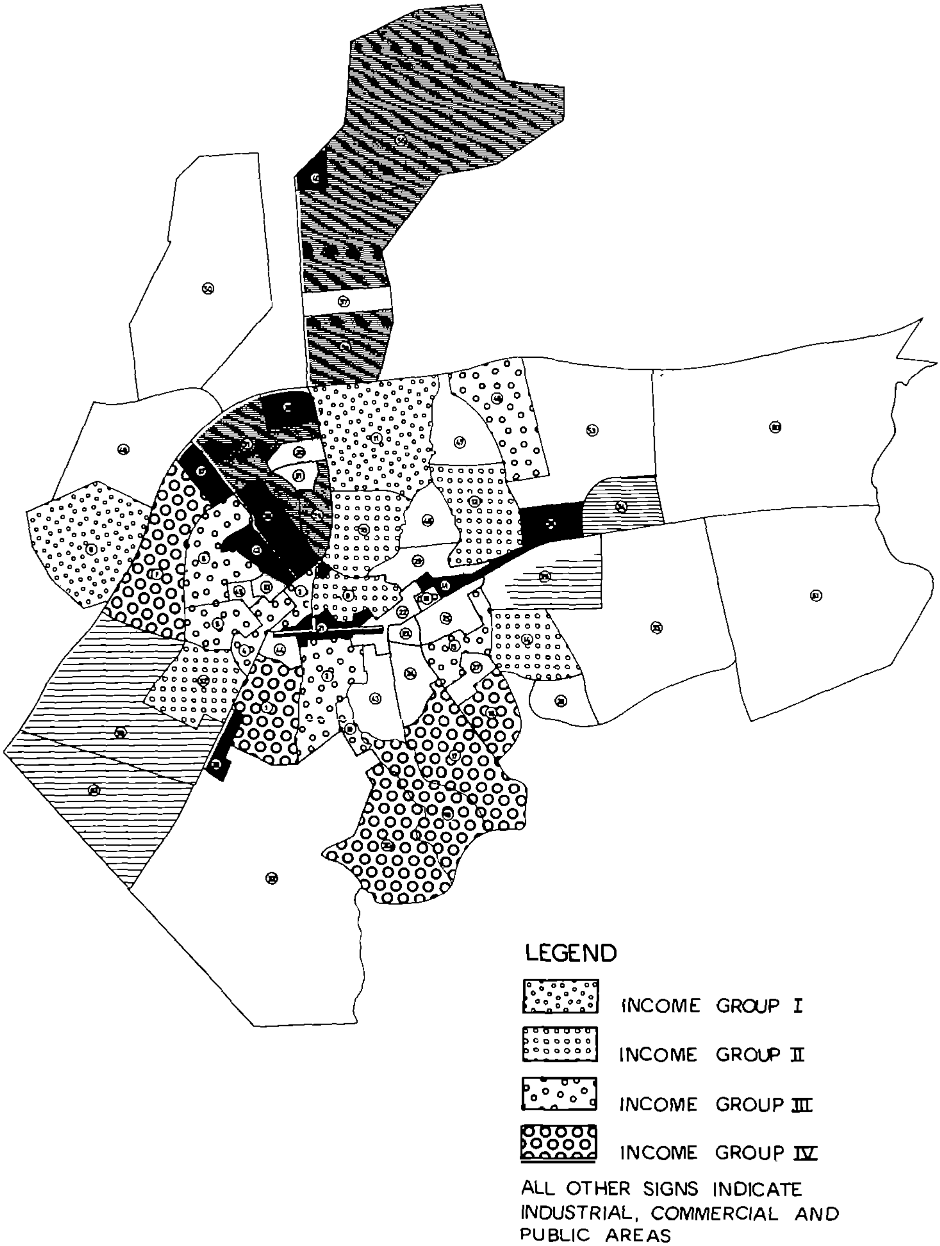


FIG. 125
INCOME DISTRIBUTION 1989

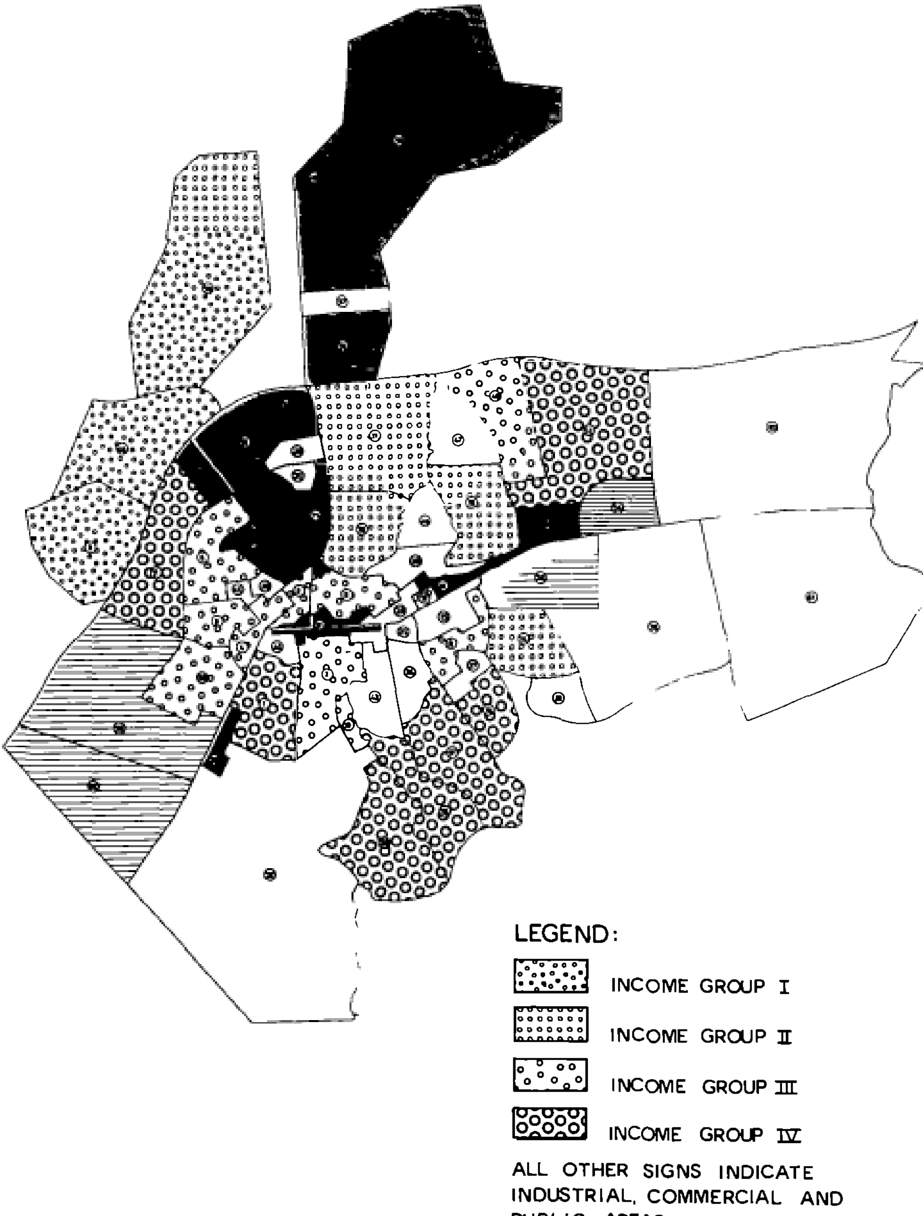
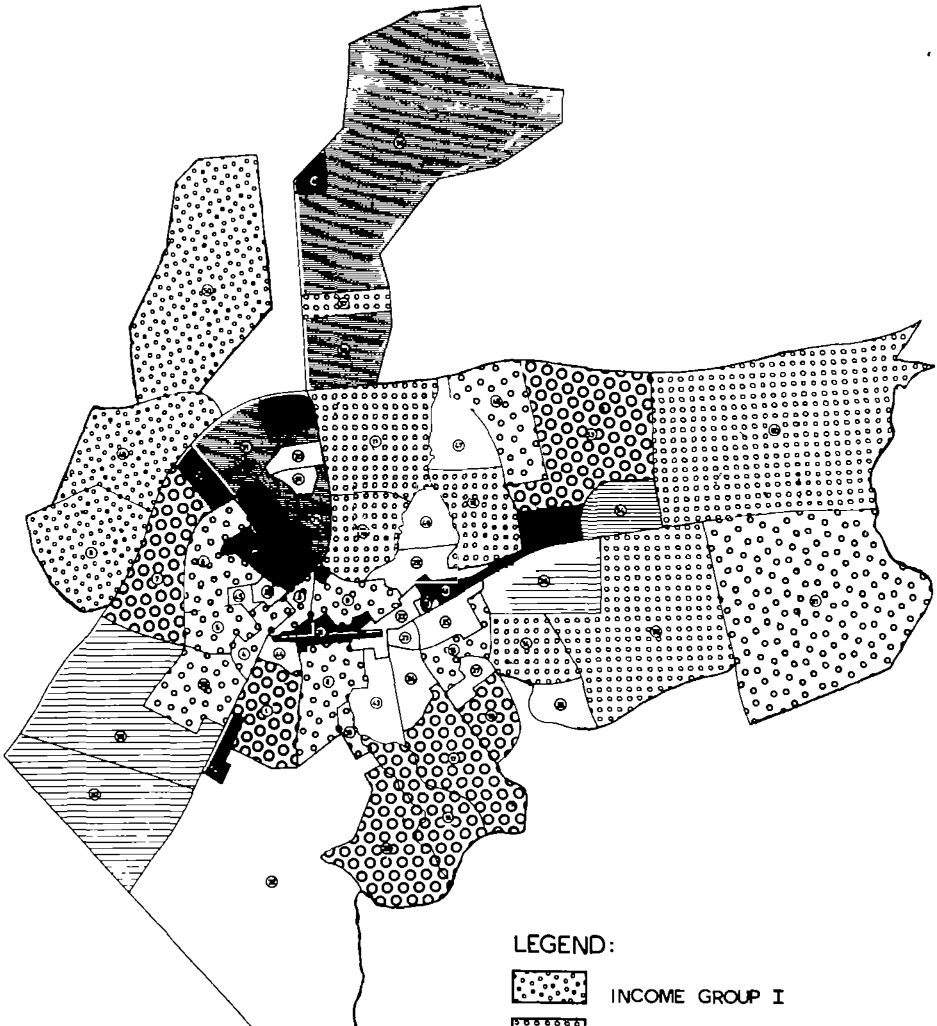


FIG 126
INCOME DISTRIBUTION 2009



LEGEND:

INCOME GROUP I

INCOME GROUP II

INCOME GROUP III

INCOME GROUP IV

ALL OTHER SIGNS INDICATE INDUSTRIAL, COMMERCIAL AND PUBLIC AREAS