CHAPTER 3 FORMULATION OF DEVELOPMENT FRAMEWORK

3.1 Planning Horizontal and Objectives

3.1.1 Planning Horizon

The planning period for the aftercare study is 1999 to 2010 and corresponds to the planning horizon of 2010 identified in the National Water Master Plan. Sewerage development is aimed at selected urban centres in accordance with the strategy outlined in the following sections of the report.

3.1.2 Development Objectives

Sewage, whether domestic or industrial, must no longer be disposed of indiscriminately. Controlled disposal of domestic sewage and industrial wastewater is the only solution for safeguarding water resources and public health in Kenya. The objective of the Aftercare Study are:

1) to provide a national sewerage development plan with priorities for implementation, and
2) to provide a strategy for the sustainable development, operation and maintenance of sewerage systems

Clearly, actions to resolve the identified constraints must be taken to ensure that operating authorities have the management capacity to properly operate and maintain sewerage. Otherwise continued development will not be sustainable. A complete list of the constraints and recommended actions to overcome them is presented in **Table - 3.1.1.**

3.2 Target Areas

There are a total of 215 urban centres in Kenya. To plan for the development of sewerage by the year 2010 in all 215 urban centres would only exacerbate the difficulties of establishing priorities and create unrealistic demands for funding. As specified in the terms of reference planning will be carried out for urban centres that already have sewerage systems and a few other urban centres where social and environmental conditions merit sewerage. There are 30 urban centres with sewerage facilities and 29 urban centres where the need for sewerage development has been identified in PIP and DDP.

From the long list of 59 urban centres presented in **Table - 3.2.1** a total of 40 urban centres are selected for the development plan. The selection criteria are to include all urban centres with sewerage facilities and all urban centres with a population of 20,000. Only Kabarnet does not meet the selection criteria but has been included because ground conditions are not suitable for on-site sanitation and the risk of contaminating potable water supply is very high. Sewerage facilities for Kabarnet have been planned and ready for construction since the 80's.

The target areas, therefore, are 40 urban centres shown in **Table - 3.2.2**.

The plan includes an allowance for wastewater discharged from industry into public sewers. It is assumed that industry will be will be required to pre-treat wastewater to meet national trade effluent standards and that most industries within an urban centre will be connected to public sewers.

3.3 Strategy for Sewerage and Sanitation Development

3.3.1 Service Standards

As preceding chapters have indicated, urban centres in Kenya have well developed water supply systems serving a high percentage of the population (>90%). In comparison, sewerage remains poorly developed serving only 28% of the population living in urban centres while almost 50% rely on pit latrines. The environmental and health implications of inadequate sanitation have been further aggravated by rapid rural urban migration and a poorly maintained and failing sewerage infrastructure.

It is not a requirement of this Study to undertake a comprehensive review of on-site sanitation facilities or prepare an implementation programme for the development of on-site sanitation. However, by the year 2010 more than 7 million people living in urban centres will depend on pit latrines for basic sanitation. Providing sewerage in only part of a community will have little benefit if the health of the residents and the water resources is threatened by the unsanitary practices of neighbouring communities that do not have sewerage.

A wide range of sanitation technologies is available as illustrated in **Figure - 3.3.1**. Technical acceptable sanitation solutions are ventilated improved pit latrines, pour flush toilets, shallow sewers, septic tanks, public toilets and conventional sewers. A comparison of the various sanitation technologies is provided in **Table - 3.3.1**.

The technical feasibility of alternative sanitation systems in Kenya depends heavily on water supply services in the area, on population densities, on soil permeability, and hydrogeological conditions. These conditions vary widely from one urban centre to the another and are very site specific. Algorithms as shown in **Figure - 3.3.2** have been developed as a guide to the kinds of questions that should be asked in the selection of sanitation technology. Although they are directly applicable to many situations encountered in Kenya there will be some situations encountered where the combination of conditions will require the selection of an option that is not that suggested by the algorithm. It should not therefore be used without judgement, but as a tool for decision making.

Conventional sewerage schemes are an excellent form of sanitation for those who can afford them and have sufficient water. There are many other least cost options which, like sewerage, can provide a high standard of health, environmental protection and user convenience. The selection of the technology best suited to provide immediate improvements in sanitation should also reflect the need for future improvements as the users socio-economic situation improves. The feasibility of sanitation upgrading sequences depends very much on incremental improvements in the level of water supply. Upgrading of on-site sanitation systems is possible over time and should be considered in system planning for areas that are not covered by sewerage **Figure - 3.3.3** illustrates the typical upgrading sequence. It also shows the various service standards of water supply that can be accommodated by alternative sanitation technologies.

One of the fundamental problems in increasing sewerage coverage is the high cost and the need to have a sufficiently high per capita use of water. Where water consumption is insufficient for conventional sewerage the alternative of shallow sewers seems particularly attractive. They are designed to accept all household wastewater for off-site treatment. They consist of a network of small diameter pipes connected to septic tanks laid at flat gradients in locations away from vehicular traffic usually in the backyards and narrow alleyways of both planned and unplanned settlements. They are designed to be flushed frequently and in densely populated communities there is ample opportunity for such operation. Most solids are trapped in solids that deposit in the sewer are flushed along by successive waves of wastewater because the pipe is small making it possible to build up the required back pressure.

The United Nations Centre for Human Settlement has issued a design manual for shallow sewers based on experience in several low-income communities across the world. There is no experience in using shallow sewers in Kenya but evidence suggests that they could be a viable option for densely populated unplanned settlements within large urban centres where conventional sewerage is unaffordable and not technically feasible because of low water consumption. More research including pilot installations will be required to determine which of the non-conventional sewer options (e.g. shallow sewers) are technically acceptable and economically feasible. Problems of user acceptance and maintenance are likely in the initial stages and will require appropriate support programmes to inform the public.

Based on a review of current practice and experience in other developing countries, conventional sewerage is usually cost effective in urban zones where:

1) The population density is greater than 120 persons per hectare, and
2) Water is supplied to individual residences in sufficient quantity to procedure wastewater flows greater than 75 litres per capita daily.

In other cases properly constructed on-site sanitation systems should be used. If conditions are not suitable for on-site sanitation (plot size, soil conditions) and conventional sewer are not affordable or feasible because of low water consumption then alternatives such as shallow sewers must be considered.

The above service standards are recommended as guidelines for future sewerage development but should be re-evaluated again when preparing urban water and sewerage master plans to reflect specific conditions encountered in each urban centre.

3.3.2 Proposed Development Strategy

Based on a review of existing conditions and discussions with MWR and MOLA the following development strategy for urban sewerage is proposed:

1) Existing infrastructure should, where economically feasible, be rehabilitated before investing in new works. This approach will in most cases be more cost effective and result in more immediate benefits such as improved treatment levels.

2) Residences with water connections should have conventional sewer connections if they are located in already sewered areas.

3) Residences with water connections in presently unsewered areas should have connections to conventional sewers, or shallow sewers or septic tanks by the year 2010. The final decision on which technology to use cannot be made at this study stage and should be based on an economic evaluation of options using local conditions.

4) Residences which today have a water connection but which cannot be served by a conventional or shallow sewer connection should during the planning period improve their sanitation by upgrading their existing cesspits or septic tanks. In later years they should be connected to the extended sewer network.

5) Residences that do not have a water connection today but will be supplied with one by 2010 should, for the immediate future, be served by pour flush toilets with sludge soak-aways if they do not install flushing toilets. They should use new cesspits or septic tanks if they do install internal flush toilets. The choice between cesspits or septic tanks depends on whether enough land is available for the more efficient and cost effective septic tanks.

6) Those who are unable to afford the sanitation system that must accompany a water connection will have to rely on standpipes for their water supply. Such residents will principally use either VIP latrines or pour-flush toilets for sanitation. The choice between VIP latrines and pour-flush toilets should be left to the individual householder.

The implementation and monitoring of on-site facilities in urban centres must be formalised to make them more effective. Formalising on-site sanitation will require:

1) Setting standards for construction of pit latrines, septic tanks and soak-away pits
2) Regulating construction through the issuing of permits and follow-up inspections
3) Regulating maintenance intervals of septic tanks and cesspits through mandatory collection
4) Providing facilities for disposal of septage
5) Regulating municipal and private sludge collection services through licensing and manifest system to ensure proper disposal

Further study and assistance will be required to determine the appropriate institutional arrangements, and implementation plan. It is proposed that MWR plays a leadership role in co-ordinating the provision of planning and inspection services with other key actors such as the ministry of local authorities and local public health departments.

3.4 Future Demand for Services

The first step in the planning process is to set a realistic target for each urban centre of the number of people that will require sewerage services by the year 2010.

Sanitation needs and planning conditions are site specific and it is impossible to determine exactly how many people in each urban centre should be connected to sewerage unless simplifying assumptions are made. According to a 1973 WHO report, it was estimated that approximately 95% of the urban population in the year 2000 would be in a situation where on-site sanitation was no longer suitable. Given that only 28% of the urban population is presently connected, such a high service coverage ratio cannot realistically be achieved by the year 2010.

Most urban centres have low service coverage. If a large number of residents in an urban community do not have adequate sewage disposal the health of water resources and of other residents who do have sewerage can be adversely affected. Therefore it is assumed that some improvement over existing conditions is required.

In Mombasa, a recent water supply and sanitation study determined that only 50% of the population could afford to pay for conventional sewerage. This seems likely to be the case in most urban centres. Therefore 50% is assumed to represent the maximum economically feasible level of sewerage development for full cost recovery. Working with 50% as a starting point, sewerage development is planned for 40 urban centres: 30 that already have sewerage systems and 10 more where there is an urgent need because on-site sanitation conditions are inadequate. The level of investment required to achieve the 50% target is larger than the forecasted investment funding therefore a lower target is required. More moderate service targets are selected on the basis of population size as shown in the following table. These individual targets translate into serving 38% of the total urban population by the year 2010. This 10% improvement is substantial considering the urban population is expected to double over the period. The corresponding investment requirements are considered achievable if donor support is provided at historical levels. This large increase, driven by rapid population growth, will require a considerable effort in sewerage development activity.

Proposed Sewer Connection Ratio

Population in urban centre	% of population connected to sewer
P > 300,000	50%
300,000 < P < 100,000	40%
100,000 < P < 20,000	25%
P < 20,000	15%

The ratio is larger for cities with larger populations because these will generally have a more people living in high density zones where there is a greater potential for health problems and environmental pollution. Smaller sized urban centres have a much smaller ratio assuming of course that they are typically less densely populated and on-site sanitation is generally suitable except in areas such as the city centre.

In some cases where urban centres already have a higher service ratio than those proposed the strategy will be to continue sewerage development, just keeping pace with population growth to maintain existing service ratios.

By following those target ratios, 38% of the total urban population would be connected to sewerage by the year 2010. This represents a 10% improvement over the current service ratio. In real terms this is an ambitious target considering the large increase in population growth that will occur and represents a net 245% increase in the total number of people served. by sewerage schemes.

The relationship between population growth and target sewerage service coverage is shown in **Figure - 3.4.1**. The actual service ratio for selected urban centres is shown in **Table - 3.4.1** and the overall targets achieved for urban cities classified by population size is shown in **Table - 3.4.2**.

3.5 Forecast Sewerage and Septage Volumes

The amount of wastewater produced by the consumption of water and the amount of solids produced by various on-site sanitation systems are estimated in order to provide an assessment of the sewage treatment and septage disposal facilities required in the future.

The production of sludge from stabilisation ponds is not significant in quantities, therefore, no estimates are made. There is no requirement for specialised sludge treatment at this time and none is anticipated in the future. The practice of sludge drying beds and land application is quite adequate and requires no special planning at this stage.

3.5.1 Dry Weather Sewage Flow

Dry weather wastewater flows are usually calculated on the basis of land use and the quantity of water consumed by different land use classifications. Since land use data for each urban centre is unavailable this study estimates wastewater flows on the basis of averages derived from more detailed data available to previous master plan studies. It is assumed that the averages are typical for most urban centres and will provide reasonable estimates for programme planning purposes. The analysis of six mid sized urban centres forms the basis for the assumption of basic parameters used in the estimate of wastewater flows as follows:

Urban Centre	Mombasa	Nakuru	Kisumu	Eldoret	Thika	Meru	Averages	Value used for planning
Population	580,000	250,000	231,000	220,000	156,000	124,000		
% Domestic	50	64	40	60	40	60	52	60
% Industrial	20	4	30	30	40	30	26	20
% Others	30	32	30	10	20	10	22	20
Average domestic unit consumption (lpcd)	91.6	42.5 (1)	104	89	87		93	93
Infiltration/inflow % of domestic flow	10	20			20		17	20
Income Distribution								
% High		15	20		5		13	10
% Medium		54	30		30		38	40
% Low		31	50		65		49	50
Data source	Master plan	JICA Study	JICA Study	Master plan	Master plan	JICA study		

Note: Value not used in average because it is abnormally low due to poor water supply conditions

Dry weather flow received at the treatment works consist of wastewater from various sources:

1) Domestic sewage,
2) Industrial wastewater,
3) commercial/institutional and public areas
4) groundwater infiltration
5) surface water inflow

The method of estimating wastewater flows is summarised in **Figure - 3.5.1**. The average per capita sewage yield of 93 litres per day compares well with the per capita sewage yield of 101 litres per day based on Kenyan guidelines and the average income distribution as shown in the following table:

Domestic Wastewater 2010	Unit water consumption (lpcd)	Wastewater Production Ratio	Wastewater Yield (lpcd)	Assumed Income Distribution (from analysis of 3 urban centres)
High income	250	0.75	188	10%
Medium income	150	0.80	120	40%
Low income	75	0.85	64	50%
Average	123	0.82	101	

Note: unit consumption and yield are as recommended by Kenyan design guidelines for sewerage.

A review of data from previous master planning studies carried out in six urban centres indicates that on average the total sewage flow is composed of domestic sewage (60%), commercial/ institutional sewage (20%) and industrial wastewater (20%). The average domestic wastewater flow is approximately 93 litres per capita daily. Therefore, using the above percentages the total base sewage flow including residential, commercial, institutional and industrial is 155 litres per capita daily.

The total base sewage flow is multiplied by a factor of 1.2 to allow for the significant contribution of water from extraneous sources such as groundwater infiltration and surface water inflow that occurs even during dry weather periods. The total dry weather flow assumed for planning purposes is 186 lpcd.

The total volumes of sewage generated by existing and future populations in the selected urban centres are estimated based on the selected target service ratios and the assumed contribution from various sources as discussed above. The volumes are compared to existing treatment plant capacities to determine the need to develop sewerage infrastructure to service the target population. The total amount of wastewater that must be collected and treated in 2010 is estimated in **Table - 3.5.1**.

3.5.2 Septage

The method for calculating the volumes of septage is shown in **Figure - 3.5.2**. The total volumes of septage generated by on-site facilities in 40 urban centres are estimated based on target service ratios. The volumes are used to demonstrate the need for septage disposal equipment and facilities.

Two methods are used to calculate the volume of septage. An average of the two results is taken for planning purposes.

Due to the poor design of septic tanks, soak-away pits are also sludge receptacles and therefore need to be evacuated. The volume of liquid from the average soak-away is added to the volume of septage to obtain the total volume of liquid waste that must be handled at treatment facilities in urban centres.

The amount of septage waste generated from on-site systems in the year 2010 is presented in **Table - 3.5.2**.

3.6 Planning Criteria

A flow diagram presented in **Figure - 3.6.1** provides an overview of the waste stream (liquid and solid) showing the management processes from source to disposal. The figure also provides a summary of the number of people contributing to the process, the strength of the waste, and the method of disposal assumed for preparing the sewerage development plan.

3.6.1 Sewage Collection

In general there are three basic types of conventional waterborne sewers that can be designed:

1) Separate system carrying foul sewage only
2) Combined system carrying sewage plus surface water
3) Partially separate where some but not all surface water is allowed into the sewer

If a combined system is installed it is necessary to design sewer system elements with more capacity to cope with large volumes of rainwater. Combined sewers require larger diameter sewers, larger capacity pumping stations and more hydraulic capacity at treatment plants. For most urban centres in Kenya it is assumed that high intensity rainfalls would result in uneconomical designs for combined systems.

Most urban centres have implemented separate systems and it is advisable to continue this practice. However, design practice allows for some the acceptance of some very limited storm water termed "inflow", therefore, the sewer system should be considered to be a partially separate system. The wastewater forecasts provided for this study assume a 20% allowance above the normal dry weather sewage flow for inflow.

For developing programme costs in this study it has been necessary to make several general assumptions about conditions in urban centres:

(1) The target population lives in conditions that make waterborne sewerage the only technical and economically viable option for sanitation and wastewater disposal.
(2) All sewers will be partially separated and will flow by gravity, the use of pumping stations will be avoided if at all possible by judicious selection of treatment sites and layout of trunk sewers with respect to topography.
(3) Existing trunk sewers have sufficient hydraulic capacity to serve a larger population.
(4) Most large diameter trunk sewers need to be cleaned to restore hydraulic capacity.

Actual conditions will vary widely from one urban centre to the next and a site specific assessment of technical options will be required at the master planning or feasibility study stage.

3.6.2 Sewage Treatment Facilities

(1) Treatment Method

A wide range of treatment options are available and currently in use in Kenya:

1) Waste stabilisation ponds
2) Aerated lagoons
3) Oxidation ditches
4) Biological filters
5) Activated sludge

A qualitative comparison of the advantages and disadvantages of various treatment methods is presented to establish which method should be used for development planning purposes.

The treatment processes must be capable of removing inorganic material and stabilising the organic portion of the waste to produce an effluent that meets the standard and sludge that can be disposed of safely with a minimum of nuisance.

Where climatic conditions are favourable and land is readily available stabilisation ponds are generally the most suitable method of treatment. Kenya's success with waste stabilisation ponds is well documented. Ponds have three major advantages:

1) they remove excreted pathogens at a much lower cost than any other form of treatment,
2) they provide good removal efficiencies for BOD, and
3) they have a minimum of operating and maintenance requirements and produce very little sludge

A comparison of various alternatives is provided in the following table:

Item	Waste stabilisation ponds	Activated sludge	Extended aeration	Aerated lagoons	Biofiltration
BOD Removal	**	***	***	**	***
SS removal	**	***	***	**	***
Faecal coliform removal	***	*	*	**	*
Virus removal	***	*	*	*	*
Industrial organics removal	**	*	*	*	*
Heavy metals removal	**	*	*	*	*
Simple and cheap construction	***	*	*	**	*
Simple operation	***	*	*	**	*
Land requirement	*	***	***	**	***
Maintenance costs	***	*	*	**	*
Reliability	***	*	*	**	*
Energy demand	***	*	*	*	**
Minimal sludge production	***	*	**	**	**

Note: * Good, ** Fair, *** Poor
Source: Notes on the design and operation of waste stabilisation ponds in warm country climates of developing countries, World Bank technical paper No. 6, J.P. Arthur.

In urban centres where land availability is small and a more energy intensive treatment method must be considered it is generally more cost-effective to provide aerated lagoons where receiving streams do not require tertiary treatment.

For the purposes of preparing a national sewerage development plan it is assumed that waste stabilisation ponds will be constructed in all urban centres where sewerage treatment works are required. It is also assumed that industrial waste pre-treatment programmes will be implemented and enforced in all large urban centres. The final selection of treatment method will depend on site-specific conditions and should be evaluated at the feasibility study stage based on a detailed assessment of technical and economic criteria.

Waste stabilisation ponds are subdivided into three types:

1) anaerobic
2) facultative
3) maturation

Anaerobic ponds are generally deep ponds in the order of 3 to 4.5 m deep. Treatment occurs under anaerobic digestion and produces methane gas. The mechanism for BOD removal is considered to be primarily sedimentation. Anaerobic ponds result in high BOD removal rates and in the digestion of sludge. They are normally provided to reduce the BOD loading on other ponds in the system with a resulting saving of land space. The combination of anaerobic ponds and a secondary facultative pond in any system is generally preferred as it usually reduces the overall land requirement for a system producing the desired effluent quality compared to a single primary facultative pond. It provides the additional advantage of:

1) buffering the secondary facultative ponds from wide variations in flow
2) acting as a solids settlement basin, thus reducing sludge accumulation in subsequent ponds
3) enabling anaerobic breakdown of some refractory compounds of raw sewage that are slow to degrade aerobically, making them a good choice where there is a substantial amount of industrial wastewater
4) Protecting algal populations in the secondary facultative ponds from slug doses of toxic compounds such as heavy metals, etc.

Facultative ponds provide aerobic stabilisation of waste in the surface layers and anaerobic digestion in the lower layers. Oxygen is supplied by the photosynthesis of algae. Facultative ponds are usually 1.2 to 2 m deep. When facultative ponds are the first in a series of ponds they are named "primary" facultative. When they are second in line after an anaerobic pond they are termed "Secondary facultative". Primary facultative ponds generally function well where the raw sewage flow rate is low or the sewage is very weak achieving satisfactory treatment without anaerobic pre-treatment ponds.

Maturation ponds are usually about 1 m deep and act as polishing ponds. They are used as an effective method of reducing the levels of pathogenic organisms released in the effluent by prolonged hydraulic retention time. They also provide a marginal reduction in BOD.

The use of a primary facultative pond will probably not provide the desired level of treatment in most urban centres. For strong wastes (>400 mg/ℓ) which is usually the case in Kenya the use of anaerobic ponds as a pre-treatment unit ahead of the facultative pond is advantageous since it reduces the organic loading of the facultative pond and thus minimises the land requirements of the whole pond system. For planning purposes it is therefore assumed that the design should consist of at least two anaerobic ponds followed by secondary facultative ponds and two or more maturation ponds to reduce faecal coliform counts.

3.6.3 Septage Disposal

It is assumed that specially constructed anaerobic ponds added in front of the normal treatment process will provide treatment of septic liquid wastes. These ponds, depending on their depth and operating characteristics will need to be de-sludged approximately every five years. The anaerobic ponds and facultative ponds and maturation ponds will need de-sludging every 15 years and will not contribute a significant amount of sludge if grit removal facilities are well maintained and not by-passes by storm flows.

For urban centres where sewage treatment already exists or is proposed than facilities for the treatment of liquid waste will consist of specially designed anaerobic treatment ponds dedicated to the pre-treatment of septic waste. There is little experience in Kenya with the use of such ponds but there is no reason for suggesting that design and operation is different from other anaerobic ponds except that the waste material is stronger than domestic sewage.

Currently most municipalities discharge septic wastes directly into the facultative ponds, which in some cases may contribute to organic overload. It is, therefore, recommended that all treatment facilities in the future be provided with separate anaerobic ponds to receive and pre-treat septic waste before discharging into the normal wastewater treatment process.

Septage collection and disposal services need to organised and properly regulated. Many local municipalities will need new scavenging trucks and in greater numbers than the current fleet. The required number of trucks should be included during the equipment survey identified under operation and maintenance improvements. Further study will be required to determine how best to regulate and control private services for collection and disposal. A licensing and manifest system is the usual way of regulating septage haulers but this will require inspectors and administrative systems that are not currently in place.

3.6.4 Disposal of Sludge from Treatment Plants

There are generally two methods for the disposal of sludge at treatment facilities:

1) discharge to sludge drying beds, or
2) discharge to dewatering and digesting facilities

For disposal of sludge from anaerobic and facultative ponds the current practice of using sludge drying beds is simple, low cost and effective. The only condition is that the sludge must be stored and dried for over 12 months in order to ensure that the material is pathogen-free.

Conventional works produce large quantities of sludge and require a more sophisticated process for sludge disposal:

1) dewatering followed by
2) digestion followed by
3) drying

In the sewerage development plan it is assumed that the capacity of conventional treatment works will not be increased therefore existing sludge facilities are assumed to be adequate.

3.6.5 Wastewater Strength and Effluent Criteria

Wastewater strength is normally expressed in terms of the oxygen demand exerted by the waste matter during oxidation. The most commonly used parameters are Chemical Oxidation Demand (COD where wastes are oxidised chemically), and Biochemical Oxidation Demand (BOD, where wastes are biologically oxidised through bacteriological degradation). The oxygen demand after five days of biodegradation is the most commonly used parameter since it can be measured in a reasonably short period of time and generally has a fairly consistent relationship with the ultimate BOD.

The BOD per capita in Kenya has been found to vary between 25 grams/day to 60 grams per day. These figures include sullage, which has a far greater impact on BOD than dietary variations on the BOD of sewage. The value most commonly used in design is 50 grams/capita/day as recommended in the WHO Guidelines for design of sewerage facilities in Kenya. This value is probably on the high side but is used for planning purposes because it provides a safe estimate.

The strength of influent raw sewage to the treatment works depends not only on domestic per capita contributions but also on the load contributed by industry which tends to increase BOD and the amount of "clean" groundwater and surface water that enters the sewer which tends to decrease sewage strength. The average BOD obtained from 26 samples taken different treatment works is 480 mg/ℓ. This value is not used since too few samples were taken to be representative and the unusually prolonged wet weather associated with El Nino during the sampling period probably contributed to the dilution of wastewater flows. A value normally used in design around Kenya is 550 mg/ℓ and is assumed for planning purposes.

The National standard for discharge to a receiving stream specifies two main effluent parameters that must be considered in the design of sewage treatment works:

1) BOD_5 not to exceed 20 mg/ℓ, and
2) Faecal coliform not to exceed 5000 MPN per 100 mℓ.

These standards are based on the Royal Commission Standard and the BOD and other parameters may not be achievable or appropriate in the majority of cases where waste stabilisation ponds are used. This is because:

1) The BOD and SS of pond effluents depend to a large extent on the algae concentration, and are not, therefore a good measure of the degree to which the sewage has been treated.
2) Where water is discharged into a river or watercourse, where water will be abstracted downstream for drinking or irrigation, a strict bacteriological standard is required.

A review of literature suggests that effluent standards should be based on the intended end use of the effluent. Arthur J.P., Notes on the Design and Operation of Waste Stabilisation Ponds in Warm Climate Developing Countries, provides the following guidelines:

Method of re-use	BOD_5 mg/ℓ	Fecal Coliforms[a] MPN/100 mℓ
Irrigation of trees and other non-edible crops	60	50,000
Irrigation of citrus fruits trees, fodder crops & nuts	45	10,000
Irrigation of sugar cane, cooked vegetables [b]	35	1,000
Discharge to receiving streams [c]	25	5,000
Unrestricted crop irrigation	25	100

Notes: a – these concentrations should not be exceeded on 80% of the samples
b – irrigation should stop 2 weeks before picking
c – depends on dilution available; effluent should contain less than 105 algal cells/mℓ

These figures represent rough guidelines. Effluent quality may have to satisfy other standards under particular circumstances or conditions. A review of literature on the performance of waste stabilisation ponds in east Africa and the results of sampling during this study would seem to indicate that a BOD_5 of 20 mg/ℓ is achievable if the sample is filtered to remove algae.

The other main effluent parameter in the National standard that affects the design is faecal coliform. Where discharge is into a river or watercourse that is likely to be used for domestic purposes downstream, a standard that includes bacteriological parameters is required. A review of current literature suggests a value of 1000 MPN per 100 mℓ is appropriate where water will be used downstream for domestic purposes. This value is easily achievable with maturation ponds as shown by the results of samples taken several facilities during this study.

For the purposes of preparing a sewerage development plan the following standards for the main effluent parameters are therefore proposed:

1) BOD_5 not to exceed 20 mg/ℓ when filtered to remove algae
2) Fecal coliforms not to exceed 1000 MPN per 100 mℓ

3.7 Strengthening Operations and Maintenance

Very little information on the management and organisation of operations and maintenance was available to the Study. Local authorities should be structured to perform and monitor operation and maintenance, administer budgets, record and retain system information, enforce sewer bylaws, plan for repairs and future system growth. Few of the local authorities surveyed can meet these requirements. It is, therefore, proposed to strengthen operation and maintenance capacity as follows:

3.7.1 Increase Operating Revenue

Development projects will not succeed if policies are not in place to generate the revenues required to sustain the services provided. The ultimate goal of every service provider should be to establish a commercially viable organisation with a long-term view to privatisation.

The rehabilitation and construction of new sewerage infrastructure should be accompanies by specific interventions to improve the management of the assets. This should include policy reforms to provide greater autonomy to the municipalities, appointment and training of key municipal staff, improving revenue collection, and better financial management and accountability. Proposals for improving financial management are discussed in the supporting report on institutional strengthening.

Since operating revenue for sewerage is based on water consumption it is imperative that recommended improvements for water supply systems be implemented. These are:

1) Improving levels of service water supply
2) Reducing UFW
3) Improving metering
4) Improving customer billing and collection systems

Other institutional changes will also have a significant impact on improving revenue for sewerage. These changes are:

1) Establishing tariffs aimed at cost recovery
2) Linking water and sewage management within one authority

3.7.2 Establish Planning and Design Standards

Design factors affect long-term maintenance. It is often difficult to balance construction costs against operating and maintenance costs. However, quality design keeps costs and problems associated with O&M to a minimum. National design codes and standards should be developed to ensure consistent planning, selection of appropriate technologies and materials that are suitable for conditions encountered in Kenya.

Most designers have no maintenance experience. While codes of practice, and standards are important, they cannot substitute for practical operations experience. It would be advisable, therefore, to establish a review process to obtain input from qualified maintenance managers or operators during the development of design specifications and drawings for investment projects. Although engineering expertise is available within MOLA and MWR there is little experience with operation and maintenance management. It is recommended that as part of every future investment project assistance from externally sourced operating experts be provided in order to ensure selection and application appropriate technology.

3.7.3 Integrate Sewerage Development with Water Supply Development

The sewerage infrastructure development plan presented in the Aftercare Study is consistent with plans for water supply. Water and sanitation projects should be considered together in order to ensure that there is a means for disposing of wastes resulting from water supplied through house connections.

Institutional improvements for integrating the water and sewerage sector are discussed further in Chapter 11. These are:

1) Improved coordination and communication between MOLA and MWR
2) Creation of commercially viable water undertakers at the local level that also have responsibility for sewerage

3.7.4 Improve Staff Training and Hire Qualified Personnel

The determination of staff requirements and skills requires a detailed working knowledge of the collection and treatment system and includes variable such as: level of service expected and funded, age of system and materials used, travel distances, type of treatment process among as well as many other variables. No single formula can be sued to determine the staffing needs of a particular system.

The effectiveness of maintenance departments depends fundamentally on the numbers and quality of the staff. Most urban centres cannot operate and maintain the proposed wastewater facilities with the current level of staff. Attempts at improving sewerage in the past have been crippled by the severe national shortage of competent personnel at every level from professional engineers, to plant operators, to sewer maintenance works. More staff will be required to implement and operate the many projects proposed. It is recommended that the following actions be undertaken within each operating authority under the combined supervision of MWR and MOLA:

1) a detailed review of organisational structures, staff establishment and qualifications needed;
2) a detailed audit of personnel already in post, their qualifications and experience against their job descriptions;
3) identification of: vacancies, training needs for existing staff, non-performing surplus staff; and
4) development of a programme of: recruitment, training, or transfers to other more suitable positions

As a general guideline the following staffing levels are recommended for operations and maintenance departments:

Function	Position	Population Connected to Sewerage				
		10,000 < P < 25,000	25,000 < P < 50,000	50,000 < P < 100,000	100,000 < P < 300,000	300,000 or more
Management & Process Control	Manager	0	0	1	1	1
Treatment Works Operations & Process Control	Superintendent	0	0	1	1	1
	Trade effluent inspector	1	1	2	2	4
	Technical assistant	0	0	1	1	1
	Laboratory technicians	0	1	1	2	2
Treatment Works Maintenance	Foreman	1	1	1	2	2
	M/E tradesmen	0	1	2	2	4
	Labourers	2	3	4	6	10
	Drivers	0	1	1	2	4
	Watchmen	1	1	1	3	5
Collection System Maintenance	Superintendent	0	0	0	1	2
	Foreman	1	1	2	4	6
	M/E tradesmen	0	0	1	2	3
	Labourers	4	6	10	20	30
Totals		10	16	28	49	75

The numbers for treatment works staff are derived in part by comparing the number of staff reported in the survey for various municipalities to typical requirements identified in literature on treatment pond O&M. Other adjustments to staffing levels are made based on JICA's experience with the sewerage development projects in Nakuru, and Kisumu.

The training needs for various operating authorities must be reviewed against the latest Action Plan for KEWI to see if they can be accommodated within the planned implementation schedule. If not, KEWI's resources should be further strengthened in both scope and capacity to accommodate larger numbers of trainees from the sewerage sector.

Local authorities will need to budget sufficient funds to increase the level of training and competence of its employees. MOLA may have to subsidise training from its own budget until operating authorities can generate sufficient revenue.

The following training needs are anticipated for collection systems and treatment plant workers:

1) Sewer inspection and condition assessment
2) Sewer repair and maintenance
3) Inspection of house connections
4) Mechanical maintenance; valves, screens, pumps
5) Electrical maintenance; motors, controls, electronics
6) Preventive maintenance management techniques
7) Operation and maintenance of waste stabilisation ponds
8) Operation of aerated lagoons and other advanced biological treatment processes
9) Biology and chemistry for treatment plant operators
10) Process monitoring and control techniques
11) Laboratory skills

12) Bylaw enforcement
13) Inspection of industrial wastewater processes

3.7.5 Procure Required Facilities, Tools and Equipment

Proper facilities, equipment and tools are essential to collection and treatment operation and maintenance. Without them, even the best-trained and motivated staff will be ineffective.

A lack of transportation, poor equipment, and a lack of tools often handicap local authorities responsible for maintenance. Much of the equipment and vehicles that were observed during the field visits and survey are old and in disrepair. Much equipment has been scavenged to provide the spare parts that are no longer available.

The local authorities did not provide the information requested on equipment needs however from discussions with superintendents at a number of municipalities the following list of general observations can be made:

1) In general vehicles for moving around the sewer maintenance district are unavailable, the number of staff outweights the number of vehicles.
2) Rodding equipment breaks down often and sometimes has to be borrowed from a neighbouring urban centre.
3) Small tools for removing obstructions are generally available but larger sewer cleaning equipment for dredging sediments out of sewers is not available.
4) Pumping equipment for by-passing sewers during repairs is not available in most smaller urban centres.
5) Trucks and heavy equipment required for repair of mains are generally too few to support the number of work crews.
6) Most local authorities do not have sludge pumps for cleaning ponds and must wait for one from MWR to become available.
7) Only two three authorities have properly equipped laboratories for monitoring process parameters.

Specific equipment requirements for each urban centre should be examined in detail during the feasibility study stage and included in as part of the capital investment project. It is recommended that the following actions be undertaken within each operating authority under the combined supervision of MWR and MOLA:

1) Review maintenance facilities needs (equipment yard, office space, materials and spare parts storage)
2) Review and prepare an inventory of existing tools and equipment to identify what is required
3) Assess what equipment, vehicles and tools are needed for maintenance
4) Rank items required in order of priority, obtain prices and identify costs in future operating budgets

5) Obtain funding to construct required facilities and purchase required tools and equipment. Proceed with purchasing on an annual basis in order of priority based on level of funding available
6) Account for the cost of depreciation and identify equipment and tool replacement costs in annual operating budget

3.7.6 Implement Preventive Maintenance and Standard Operating Procedures

When equipment and manpower needs have been determined, the next step is to plan how these resources should be used. Proper operation and maintenance of sewerage facilities is essential in order to provide a system that protects public health and the environment. Maintenance is aimed at:

1) Keeping sewers clean to maintain their hydraulic capacity and prevent overflows
2) Preventing physical deterioration of facilities to protect existing investments, prevent costly repairs, and extend the useful life
3) Ensuring that treatment processes operate as intended to provide the required level of treatment

Some of the most critical maintenance functions that are currently not carried out in Kenya are:

1) Inspection of sewers from the inside to determine physical conditions and maintenance needs
2) Assessment of sewer rehabilitation and replacement needs
3) Flow monitoring and sampling to identify planning and design criteria, problems such as infiltration in leaking sewers
4) Routine cleaning and flushing to maintain hydraulic capacity and prevent foul odours and conditions that lead to corrosion
5) Preventive maintenance to mechanical and electrical components to minimise equipment failure and prevent the overflow of raw sewage to the environment
6) Removal of sludge from anaerobic ponds at 2 to 5 year intervals
7) Removal of sludge from facultative ponds at 15 to 20 year intervals
8) Monitoring and control of treatment process parameters
9) Monitoring and regulation of industrial effluents into public sewers

Improved management cannot be attained with poor, untrained manpower. Steps must be taken to hire well-trained personnel as well as skilled trades persons. In the absence of skilled in-house trades people, it may be more cost effective to contract out mechanical and electrical maintenance of treatment works and pumping stations.

Crisis management tends to be more expensive because the size of the problem tends to grow with time. Preventive maintenance on the other hand includes regular inspection and scheduling routine maintenance before problems occur for the purpose of extending equipment life, reducing maintenance costs and increasing reliability. Sewerage infrastructure represents a large investment and should be protected and cared for. A preventive maintenance programme is one of the best ways to keep the system in operation and in good condition.

In the long term it is recommended that preventive maintenance programmes be developed within each operating authority. This will require significant effort but is considered a very necessary requirement to establish sustainable operation of sewerage schemes. The success of implementing PM will require properly trained people with an understanding of the maintenance scheduling and planning methods as well as the expected benefits. Successful implementation will require full time assistance and support from externally sourced engineers and experienced maintenance programme managers for a period of 3-5 years in each operating authority.

In the short term it is recommended that the following actions be undertaken with the assistance of appropriate experts as part of future investment projects and as a condition to project on-lending:

1) Prepare a detailed sewer inventory identifying pipe size, material and location
2) Prepare topographic survey along sewer lines and a house connection survey
3) Prepare utility maps
4) Inspect all trunk sewers and manholes complete with an assessment of condition and rehabilitation needs (this will require contract services for closed circuit television)
5) Assemble an inventory of all mechanical and electrical equipment and prepare a manual with manufacturers operating and maintenance instructions, and replacement parts list
6) Prepare a maintenance schedule for all M&E equipment
7) Prepare a maintenance schedule for regular inspection and cleaning of trunk sewers
8) Prepare a monthly and weekly manpower scheduling procedure
9) Design and implement a work order system to track all maintenance activities including corrective and emergency repairs
10) Write standard operating procedures for process control, equipment operation and maintenance, laboratory procedures, and data recording

3.7.7 Implement an Industrial Wastewater Pre-treatment Program

Industrial effluent laws are in place but enforcement is very weak because there is a lack of money, manpower, and equipment to implement a comprehensive programme at the local level.

Developing a strategy and implementation plan for the enforcement of industrial waste pre-treatment will require further study. There are various institutional options, legislation, administrative and operational requirements that must be examined before deciding on the best strategy.

Typically, pre-treatment programmes are implemented at the local authority level where the sewerage operator is responsible for inspecting and monitoring industries connected to its sewer system to ensure compliance with local sewer bylaws.

Implementation of a pre-treatment programme at the local level usually includes the following elements:

1) Development of an inventory of industrial discharges to the public sewer system;
2) Adoption of an industrial pre-treatment bylaw;
3) Purchase of monitoring and laboratory equipment;
4) Sampling and analysis of industrial effluents to ensure compliance; and
5) Establishment of administrative procedures to obtain compliance with regulations

Once an implementation strategy has been developed, technical assistance and funding will be required to support the implementation of industrial waste programmes in major urban centres across Kenya.

3.7.8 Improve Sewerage Works Operations

Where existing treatment works are inoperative they must be rehabilitated as soon as possible. Treatment works that are overloaded must be expanded to serve existing and future sewered populations.

Other treatment works that are operational but do not meet effluent standards should be the subject of an operational review to determine what can be done to optimise treatment levels. In addition, the operational review should establish standard operating procedures and identify the equipment and training required for operators to monitor and control the process.

CHAPTER 4 SEWERAGE INFRASTRUCTURE DEVELOPMENT PLAN

Chapter 3 considered the strategy and planning criteria for the development of sewerage in Kenya. This section identifies the proposed sewerage projects and phasing required to meet the forecasted sewage flows in the year 2010. Project cost estimates are prepared in order to provide a basis for sewerage development programme budgeting. A list of facilities and the required projects is presented in **Table - 4.1.1**.

4.1 Rehabilitation Plan for Sewerage Systems

(1) Treatment works

Where existing treatment works are inoperative they must be rehabilitated as soon as possible. Treatment works that are overloaded must be expanded to serve existing and future sewered populations. Other treatment works that are operational but do not meet effluent standards should be the subject of an operational review to determine what can be done to optimise treatment levels. In addition, the operational review should establish standard operating procedures and identify the equipment and training required for operators to monitor and control the process.

Based on a survey of existing conditions major rehabilitation of sewerage treatment works is required at 15 facilities. Major works are defined as those works that require significant capital investment. Other facilities not on the list may require minor repairs to mechanical or electrical equipment but these are considered small expenditures that should be planned for in operating budgets by local authorities or in investment budgets by MOLA. A list of facilities and the required rehabilitation is presented in the following table.

The removal of sludge is a major difficulty for most local authorities because they lack the required pumping equipment and vehicles to haul the wastes to a suitable dumping site. The issue is complicated by the massive size of the operations required at most sites. This type of maintenance should be contracted out to specialised companies.

Septage treatment facilities are required in each urban centre and will be incorporated into existing treatment plant processes.

Facility	Rehabilitation need
Nairobi - Dundora	Remove sludge from anaerobic ponds and facultative ponds
Kisumu - Conventional	Mechanical/electrical equipment replacement and repair
Kisumu - Nyalenda	Remove sludge and weeds from ponds
Nyeri - conventional	Repair embankments and erosion protection at maturation ponds
Nyeri - Kijango	Repair pond inlet structure, repair embankments
Kitale - conventional	Repair inlet works, replace sludge pumps, trickling filter distributor, provide erosion protection at maturation ponds
Kakamega - Shirere	Provide inlet works, repair and protect embankments, remove sludge and weeds
Thika	Remove sludge, provide new inlet works, cut grass and remove trees from embankment, provide erosion protection and improve inter-pond connections
Naivasha	Replace electrical equipment, repair mechanical equipment, remove sludge from anaerobic and facultative ponds.
Webuye	Remove sludge and repair inlet chamber
Busia	Remove sludge
Nanyuki	Remove sludge
Embu	Remove sludge
Isiolo	Remove sludge and provide embankment protection
Homa Bay	Remove sludge, provide new sludge processing equipment and clarifier
Nyahururu	Repair floating aerators, remove sludge, repair embankment protection

(2) Sewers

Rehabilitation of sewers is necessary in all urban centres. The needs vary for each urban centre and is difficult to establish exactly what is required without a more thorough study inspection of facilities and assessment of conditions. Therefore the sewer rehabilitation projects in each case are costed out on the assumption that all trunk sewers need to be cleaned, that sewers should be inspected to assess structural condition and that 25% of all small diameter sewers (150 mm) should be replaced with larger diameter pipe (minimum 225 mm).

The decision on which sewers to rehabilitate will require more information and the following actions should be taken:

1) preparation of a comprehensive sewer inventory
2) sewer inspections to determine the physical condition of infrastructure
3) assessment of hydraulic capacities to identify bottlenecks
4) ranking of rehabilitation needs in order of priority

4.1.1 Extension of Sewer Reticulation and Expansion of Treatment Works

(1) Sewer Reticulation

The rehabilitation of existing sewers should be the first priority in urban centres where the service coverage is well below target service ratios and the flows into the treatment plant are well below design capacity in most urban centres. In the short term, extensions should follow simplified designs that feed into existing trunk sewers with excess capacity. Where sewers exist in a community, efforts should be made to reinforce the number of individual service connections in order to improve flows into the sewers. In the long term, trunk sewers that do not have the required hydraulic capacity should be replaced or augmented before extensions are made in upstream drainage areas.

Sewers should not be extended into areas where individual per capita consumption of water is less than 75 lpcd. Extending the network of sewers should only proceed with the improvement of water supply services into existing and new areas.

Water Supply Condition	Treatment Work Condition	Proposed Measures	Urban Centre Subject
Water supply conditions are probably adequate to support conventional sewerage	Treatment works is operating at or above design capacity	Increase treatment capacity before extending sewer network.	Eldoret, Kakamega, Kapsabet, Kisumu, Machakos, Meru, Nairobi, Nanyuki, Nyahururu, Thika
	Treatment works has short term capacity	Extend sewer reticulation coverage up to treatment works capacity	Athi River, Karatina, Kiambu, Kisii, Muranga, Webuye
Water supply conditions are probably not adequate to support conventional sewerage	Treatment works has short term capacity	Improve water supply conditions before extending sewer network	Bungoma, Isiolo, Kitale, Mombasa, Naivasha, Nakuru, Nyeri
	Treatment works is operating at or above design capacity	Increase treatment capacity before extending sewer network. Extend sewer network only if water supply conditions improve	Busia, Embu, Homa Bay, Kericho, Limuru, Ngong, Voi

(2) Sewage treatment works expansion

Where existing sewerage treatment works are overloaded the first priority should be the expansion of the treatment works even in cases where water supply conditions are inadequate to support sewer reticulation. In this case the extension of sewer reticulation should be included as part of the treatment works expansion project and phased to match completion of the sewage works or future improvements in water supply conditions.

In general, where treatment facilities already exist there are three possible alternatives that must be considered in assessing future development:

1) rehabilitation and expansion of existing facilities, or
2) rehabilitation, with expansion of capacity with treatment works at a new site, or
3) abandoning existing sewage treatment works and replacing with new.

The decision to maintain existing facilities in operation should be based on an economic evaluation of the site-specific technical options. This type of detailed evaluation should be done when a master plan for the urban centre is developed. The conditions in each urban centre will be different depending on:

1) the need to expand capacity,
2) the condition of the existing works,

3) the availability of land for expansion at the same site, and
4) the cost effectiveness of consolidating all treatment facilities in one location

For the purpose of establishing programme costs it is assumed that it will generally be cost effective to rehabilitate existing waste stabilisation ponds. There are of course a few exceptions where the existing ponds are no longer in use or in such disrepair that it would be more cost effective to relocate and build a new facility.

Where existing conventional treatment works are concerned, it is difficult to assess with the information available from this study whether or not it is economical to rehabilitate them and keep them in service. Generally speaking where these works are operational it is probably worth keeping them in service and adding waste stabilisation ponds to improve performance and cope with the incremental flows. This has been the case in recent upgrade projects in Kericho, Nakuru and Eldoret. Where land space at the existing facility is insufficient, then it is assumed that expansion of existing facilities will consist of adding waste stabilisation ponds at a new site.

In the case of Nairobi (Kariobangi conventional), Mombasa (Kizingo primary sedimentation) and Kakamega (Kiambi waste stabilisation ponds) the facilities are in extremely poor condition and in a bad location. It is assumed that it would be technically and economically advantageous to abandon these plants and divert flows to a new facility with more capacity.

The need for sewage treatment works in urban centres with existing facilities is identified in the following table:

Capacity Condition	Proposed Measures	Urban Centre Subject
Short term (1998-2005) More treatment capacity is required because existing facilities are overloaded	Rehabilitate and/or expand existing treatment works	Kisumu (Nyalenda), Kapsabet, Limuru, Kakamega, Nairobi (Dundora), Nanyuki, Nyahururu
	Provide new treatment works	Busia, Eldoret, Embu, , Kericho, Homa Bay, Machakos, Meru, Ngong, Thika, Voi
Long-term (2005-2010) provide more treatment capacity to meet target for 2010	Rehabilitate and/or expand existing treatment works	Bungoma, Isiolo, Kakamega, Karatina, Kisii, Muranga,
	Provide new treatment works	Kitale, Kisumu, Mombasa, Nakuru, Naivasha, Nyeri,

4.2 Cost Estimates

Cost estimates for the facilities required in each urban centre have been established for programme planning purposes and their limitations are discussed below. Records of unit costs are not systematically kept in Kenya and, therefore, some research was required to establish the cost estimates given in this report. Unit costs where collected from government offices, local consultants and manufacturers. The unit costs where also cross-checked against prices quoted in tenders for recent sewerage development projects and results of recent planning studies.

It is difficult to determine typical unit costs for any method of sewage disposal; costs vary for example, with location, with ease of excavation, and with topography. The depth and, therefore, the cost of excavation for sewers, which flow by gravity and must therefore always fall, depends absolutely upon the local topography. The presence of rock or groundwater can enormously increase construction expenditure. Population density is also another important factor; costs generally fall as the density increases. To estimate the costs of sewerage development, an attempt has been made in the Study to establish average unit costs, which are applicable throughout Kenya. These costs represent typical conditions but do not necessarily apply to any particular project in any particular location.

4.2.1 Basic Conditions

(1) Basic Cost of Material and Equipment

The basic costs of materials and equipment are estimated at the price level prevailing in February 1998. An exchange rate of 1 US$ = 61.1 Kshs = 124.7 Yen (as of 10 February 1998 by "*East African Standard*") is applied in estimating the basic costs of imported materials and equipment for the whole project. The costs of materials locally available are estimated based on market price, the latest quoted price and results of the recent studies done in the country. Taxes, duties, and FOB costs are included in the estimates.

(2) Composition of Cost Estimates

The cost estimate is made for the following cost items:

1) Direct construction cost
   Costs for sewer reticulation, new treatment, expansion or rehabilitation
2) Land acquisition and compensation cost [Local portion only]
3) Administration cost [15% of direct cost]
4) Engineering cost [10 % of direct cost]
5) Physical contingencies [10% of total of 1) - 4)]
6) Price contingency [5% of foreign portion and 15% of local portion of 1) - 4)]

Project cost — Total of 1) - 6)

4.2.2 Facilities Planning and Quantities

The requirement for treatment works and sewer reticulation are summarised in **Table - 4.1.1** for each urban centre.

In Kenya there are currently no planning or design standards. This has lead to a variety of technologies, some inappropriate, resulting in systems that are difficult to operate and maintain.

Since design factors affect long-term maintenance, national design codes and standards should be developed to ensure consistent planning, selection of appropriate technologies and materials that are suitable for conditions encountered in Kenya.

(1) Sewer Reticulation

Sewer construction is based on pre-cast concrete pipes and manholes with costs estimated by referring to the existing facility in Muranga (p81, *Muranga's Sewerage Scheme,* May 1992).

In planning of new construction and extension of existing sewer reticulation systems, the diameter and length of pipe are determined as follows:

1) New construction and extension

i) Diameter and Length of Pipe

The diameter and length of pipe required to serve the target population is determined to estimate the costs of sewer reticulation. Costs are estimated on the basis of an average length per capita and a distribution of pipe sizes considered to be typical for most urban centres in Kenya.

The assumptions made regarding sewer reticulation quantities are shown in **Table - 4.2.1**. The table shows the assumed average depth of buried pipes, the percentage for each diameter of pipe in terms of total installed length, and the length of pipe per capita connected to the sewer system. The typical quantities of pipe of different diameters, expressed as a percentage of total length, is based on a review of existing reticulation inventories for Mombasa and Nakuru (**Table - 4.2.4**).

The total length of pipe required in each urban centre is calculated by multiplying the incremental population requiring sewer connections in 2010 by the average per capita length of 1.14 meters found from the results of the survey carried out for the Study.

ii) The depth of Excavation and Manhole

The depth of the excavation depends to a large extent on the configuration of the system, and the local topography. The depth generally tends to be shallow in upper reaches of the system where pipes with a smaller diameter are used. The depth tends to be deeper in downstream drainage areas where larger diameter mains are installed. This study assumes an average depth as shown in **Table - 4.2.2** for each pipe diameter based on averages obtained for existing installations in Kisumu.

2) Rehabilitation of existing sewer

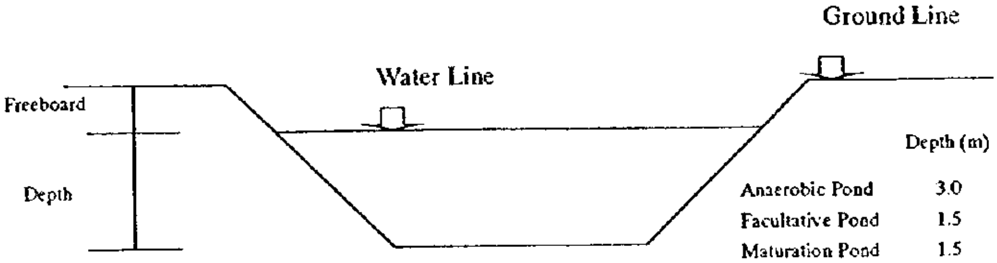
In this study, it is supposed that 25% of the 150 mm dia. and 200 mm dia. pipes will be replaced, and all the pipes with the diameters, (300 mm, 450 mm and 600 mm) will be cleaned .

Assumptions for replacement and pipe cleaning of existing sewer are given in **Table - 4.2.3**.

(2) New Treatment Works

1) Pond layout

Pond geometry is based on a study by the UK ODA (pp39-41: *Waste Stabilisation Ponds –A design manual for eastern Africa*, 1992, Leeds). From the information, the depth of anaerobic ponds adopted in the Study is 3.0 m. The depths of facultative and maturation ponds are set at 1.5 m, and a 1.0 m freeboard is added to prevent overtopping. The top of the embankment is given a 2 m width.



	Depth (m)	Freeboard (m)
Anaerobic Pond	3.0	1.0
Facultative Pond	1.5	1.0
Maturation Pond	1.5	1.0

There is little information on the optimum length to breadth ratio for ponds. An approximate ratio between the length and breadth of 2:1 is adopted in the Study based on the existing facilities in Muranga (*Muranga's Sewerage Scheme*, May 1992).

Furthermore, in planning the layout, it is assumed that there should be more than one series of ponds. This is because a facility with only one series of ponds cannot operate during its rehabilitation, reconstruction, or maintenance. As presented in **Figure - 4.2.1**, therefore, this study offers three types of layouts, which provide two or more series of parallel ponds.

2) Capacities of ponds

Pond capacities have been estimated on the basis of the UK Overseas Development Administration publication entitled "*Waste Stabilisation Ponds: A Design Manual for Eastern Africa*"(1992). The assumed influent BOD is 550 mg/ℓ.

The capacity of each pond is determined based on the design wastewater flow, called "Dry weather flow 2010" in **Table - 4.1.1**. Required capacities of anaerobic ponds, facultative and maturation ponds are calculated by the following formula:

$$V_A = 2.1X \qquad A_F = 11.2X \qquad A_M = 12.7X$$

Where X is each design wastewater flow (m^3/day), V_A is volumetric the capacity of an anaerobic pond (m^3), A_F is the area of a facultative pond (m^2), and A_M is the area of a maturation pond (m^2). The typical relation between the capacities of ponds and the dry weather flow is shown in **Figure - 4.2.2**.

The formulas above were constructed by calculating the sizes of the waste stabilisation ponds required for flows of 10,000 m^3/day 5,000, 2,000 and 1,000 m^3/day. The typical relation between these design wastewater flows and the size of anaerobic, facultative and maturation ponds is provided in **Figure - 4.2.2**.

The formulas can basically be applied to estimate the construction costs of ponds in each urban centre.

When the volume of design wastewater flow in an urban centre exceeds 10,000 m^3/day, the volume is equally divided to provide parallel series of ponds with capacities less than 10,000m^3/day.

Example:

The expected volume of Kericho's wastewater flow in 2010 is 12,685 m^3/day.

To put this volume into its treatment facility, the volume is divided to become less that 10,000 m^3/day.

In Naivasha, the divided volumes (6,342.5 m^3/day) of the design wastewater flows are put into two parallel ponds respectively. The sizes of each pond are, in this case:

VA	=	13,319.3 m^3,
AF	=	71,036.0 m^2 and,
AM	=	80,549.8 m^2.

After finding the sizes, then, these sizes are multiplied by the sufficient numbers (two parallel ponds) of each pond. In this case;

Anaerobic pond	:	13,319.3 × 2	=	26,639 m^3
Facultative pond	:	71,036.0 × 2	=	142,072 m^2
Maturation pond	:	80,549.8 × 2	=	161,100 m^2

(3) Expansion of Existing Treatment Works

The expansion of existing waste stabilisation ponds is made by increasing the numbers of ponds. Expansion is also considered for the existing aerated lagoons, oxidation ditches and trickling filter installations by adding stabilisation pond in parallel to existing processes.

1) Type of expansion

The expansion works may be classified into the following 3 types: (illustrated in **Figure - 4.2.1**).

a) Provision of one or more additional series of ponds (Type 1)

Expansion is required for anaerobic, facultative and maturation ponds.

b) Provision of additional maturation ponds (Type 2)

Expansion is required for facultative ponds.

c) Provision of Stabilisation pond to other treatment types (Type 3)

2) Capacity of expansion

This same method for finding the capacity of new ponds is applied or calculating the capacity of the expansion:

$$V_A = 2.1X \qquad A_F = 11.2X \qquad A_M = 12.7X$$

Where X is design wastewater flow(m^3/day), called "Incremental treatment capacity (m^3/day)", V_A is the capacity of anaerobic pond (m^3), A_F is the area of facultative pond(m^2), A_M is the area of maturation pond (m^2).

(4) Rehabilitation of Treatment Works

Rehabilitation at treatment works are divided into embankment protection, de-sludging and improvements to, in/out let chamber works. Since the embankments of Muranga's existing ponds are protected by pre-cast concrete (PC) (p82, *Muranga's Sewerage Scheme* May 1992), this Study designs the embankment protected by PC. To fully cover the freeboards of the ponds, the Study proposes 2.0 m of PC's length from the top to bottom.

Regarding the de-sludge work, the volume required for the de-sludge is calculated with the depth, 0.75m, from the experience of Thika (Appendix 12 of *Thika Sewerage Master Plan,* April 1998). For the other rehabilitation works, this Study also refers to the *Thika Master Plan.*

The rehabilitation of the treatment works consist of:

1) De-sludging for the anaerobic or primary facultative ponds, and any subsequent ponds if necessary.
2) Checking embankment stability, and repairing, replacing or installing embankment protection.

(5) On-going Projects

Regarding on-going projects, no facilities planning or cost estimates are made in this study.

4.2.3 Unit Costs

The direct construction cost is estimated by multiplying quantities by the unit costs of each work. The unit costs are estimated as follows:

(1) Sewer Reticulation

The construction cost of sewer reticulation is estimated by the pipe length of each diameter. The unit cost for construction of sewer reticulation is given in **Table - 4.2.5** by referring to the Appendix 11 of *Thika Sewerage Master Plan* (April 1997). The construction cost per meter includes those of pre-cast concrete pipes, excavation, and manholes at 50 m spacing.

(2) New Treatment Facilities

The typical process of the calculation for the sizes (i.e. length and breadth) is already presented in *'Capacities of ponds'* of Chapter 4.2.2. The sizes of the ponds noted in the chapter are, however, at their wastewater lines, not at the top of their embankment.

In finding the excavation costs of each pond, therefore, their sizes at the top of the embankment are essential. By considering the slope (length-to-breadth ratios of 4 to 1) of Muranga's existing facility defined as one of the typical facilities in this Study and the information of the pond geometry (p39, *"Waste Stabilisation Ponds"* 1992), the sizes of the ponds at the top of embankment can be found.

The sizes at the mid-depth and bottom of the ponds can also be calculated respectively, and, therefore, the excavation volumes can eventually be found.

In estimating the costs of the excavation, this Study uses the experience of Thika (Appendix 11, *Thika Sewerage Master Plan,* April 1997). For the embankment protection, the Study adopts that of Muranga (p82, *Muranga's Sewerage Scheme,* May 1992).

In addition to the costs themselves, the annual rising level in price should be taken into account for estimating the costs. For examining the rising level, the Study applies to the level of Thika and Muranga (*Civil Engineering Index-Cost Index 1991-1994,* 1995 Nairobi **Figure - 4.2.3**). With considering these conditions, the unit cost of the excavation can be 3.1US$. That of the embankment is 6.62 US$ in the Study. The unit construction costs are summarised in **Table - 4.2.6**.

The total construction cost consists of the excavation and embankment protection cost The relation between the costs and volume of the design wastewater flow is presented in **Figure - 4.2.4**, with the proportion coefficients which can be defined as the unit costs of the new construction.

The total construction cost of the new treatment facilities is estimated by the following formulas.

$$Y = 195.6X$$

Where X is design wastewater flow (m^3/day) called "Incremental treatment capacity (m^3/day)" and Y is total construction cost of expansion.

(3) Treatment Works Expansion

The formula presented for the new construction can also be applied to the calculation of the expansion works.

(4) Rehabilitation

The total rehabilitation cost for treatment works is estimated based on the quantities of de-sludging, area of embankment and length of pipeline required for the replacement and cleaning.

The unit costs for the Replacement of sewers are assumed to be 1.5 times of the cost for the new construction. The unit costs for rehabilitation are given in **Table - 4.2.7**.

(5) Land Acquisition

The unit cost of land acquisition for new treatment facilities and expansion is shown in **Table - 4.2.8**.

The costs for land acquisition are based on a survey of recent land costs carried out by the *Mangat, I.B, Patel and Partners Consulting Engineers*, Nairobi, Kenya during this Study.

4.2.4 Facilities Cost Estimates

Table - 4.2.9 details the quantities required to estimate the costs. The cost of treatment works and sewer reticulation in US$ is shown in **Table - 4.2.10**. The cost estimate is summarised as follows:

Item		Estimate Cost (US$)
Treatment Works	Build New Facility	66,551,000
	Expand	90,458,000
	Rehabilitation	4,717,000
	Sub Total	161,726,000
Sewer Reticulation	Build New Facility	273,426,000
	Replacement	47,200,000
	Pipe Cleaning	698,000
	Sub Total	321,324,000
Total		483,050,000
On going project	Mombasa	25,000
	Eldoret	6,000
	Total	31,000
Grand Total		483,081,000

4.2.5 Operation & Maintenance Cost

The cost of operation and maintenance (O&M) is estimated based on the following cost items:

1) Equipment maintenance and repair cost
2) Manpower cost

(1) Maintenance and Repair Cost of Equipment

Maintenance and repair cost of equipment are considered annual maintenance and repair cost as percent of capital cost in the term of economic life. The costs of operation and repair cost of equipment are estimated by referring to the data indicated in **Table - 4.2.11.**

(2) Manpower Cost

In managing the operation and maintenance, manpower is required for the management, treatment work and collection system. The numbers of the staff depending on the served population of each areas are respectively decided by referring the recent World Bank's study (1983: *Notes on the Design and Operation of Waste Stabilisation Ponds in Warm Climates of Developing Countries* Washington D.C.).

Table - 4.2.12 indicates the standard number of the desirable staff for operation and maintenance of the system and the annual manpower cost.

(3) Operation and Maintenance Cost

Tables - 4.2.13 and **4.2.14**, respectively, provide the annual maintenance and repair cost of equipment for each urban centre, and the annual manpower cost.

4.3 Implementation Strategy

4.3.1 Priorities Among Urban Centres

The previous sections have identified the various sewerage development needs in each urban centre. A key task in defining a national programme for sewerage development is the setting of priorities because not all needs can be satisfied in the near future. The following five criteria for ranking priorities among urban centres are proposed:

% of population with piped water supply but no sewer connection	Population requiring services by 2010	Potential Health & Environmental Impact	Industrial growth potential	Tourism Potential	Rating
<25%	P<20,000	nil	nil	nil	0
25 to 50%	20,000<P<100,000	Minor impact on water environment	low	low	1
50 to 75%	100,000<P<300,000	Serious impact on sensitive ecosystem	medium	medium	2
>75%	P>300,000	Contamination of drinking water source	high	high	3

(1) Percentage of population that has piped water but no sewage connection

This criteria is a direct indication of how urgently sewerage services in an urban centre are required. The larger the percentage the higher the rating. Where a large percentage of the population have piped water but no sewer connection the disposal of sullage will likely be large enough quantities to find it's way to surface drainage. Large amounts of untreated wastewater in surface drainage can affect the quality of drinking water resources in rivers and shallow wells and is a serious threat to the public health of all residents, especially in larger, more densely populated areas. The situation can even affect neighbouring communities with sewerage facilities.

(2) The number of people that need to be connected

This criteria is also a measure of the urgency and the need for services. This factor compares the number of people now connected to sewers to the number of people that would be connected to achieve the target proposed for 2010. This comparison can result in large numbers if existing service coverage ratios are very low or if urban populations are very large but in general this factor tends to favour the larger urban centres. There are many reasons for attaching a higher rating to a larger population:

1) There is more risk of health and environmental impacts
2) The cost per capita is usually lower for larger systems, in more densely populated urban centres
3) A greater number of people would benefit from improved social, and environmental conditions

(3) Potential Health and Environmental Impact

This criteria is based on two factors:

1) a qualitative comparison of the potential receiving stream impacts
2) the potential impact on potable water supplies, evaluated on the basis of statistics for access to safe water

Several urban centres will have a profound impact on the environment. Other urban centres pollute water that will be used downstream as an important source of potable water supply. In some districts access to safe water is very low and many people rely on surface water for domestic use. Urban centres in these districts have a very high potential for contaminating surface water used by rural residents in downstream reaches especially if the district is densely populated and urbanised.

(4) Industrial Growth Potential

In 1975 the Physical Planning Department prepared a study "Human Settlements in Kenya, A strategy for Urban Development". This study identified the potential growth status of urban centres by evaluating a number of criteria including industrial potential, agricultural potential, tourism potential, proximity to large urban centres, accessibility, administrative potential and level of infrastructure. The results of the evaluation are shown in **Figure - 4.3.1**. Although the study is old the assessment of industrial potential is considered valid today and has been used in recent master planning studies. Industrial potential is a measure of several factors that can influence the need for sewerage development:

1) these towns will likely grow at a much faster rate in the near future given the Government's policy to increase industrial output
2) the influx of more people and industrial development will increase the consumption of water and exert a greater demand for wastewater infrastructure
3) control of industrial effluents and wastewater treatment will be important in these industrialised urban centres to safeguard the environment.

(5) Tourism Potential

Tourism is one of Kenya's most important sources of revenue. The sanitary conditions in important tourism centres must be improved to maintain tourism as a viable industry as identified in the National Tourism Master Plan

A ranking of urban centres is presented in **Table - 4.5.1** and summarised below:

Priority	Urban Centre	Score
1	Mombasa	14
2	Nairobi	13
3	Kisumu	12
4	Machakos, Meru, Nakuru	11
5	Narok, Malindi, Kitale	10
6	Kisii, Naivasha	9
7	Maragua, Ruiru, Wajir, Thika, Kericho, Nanyuki	8
8	Garissa, Ongata, Kilifi, Nyahururu, Webuye, Voi, Eldoret, Nyeri	7
9	Mandera, Kabarnet, Muranga, Bungoma, Busia, Isiolo	6
10	Kapsabet, Homa Bay, Karatina, Embu, Kakamega	5
11	Ngong, Athi River	4
12	Kiambu	3
13	Limuru	2

4.4 Strategy for Project Scheduling and Phasing

The scheduling of sewerage development projects should follow the relative order of priorities established by the ranking of urban centres in order to meet the target service coverage ratio set for 2010. The actual timing of a sewerage project will depend on the funding available and on the timing of water supply improvements where low unit consumption does not support waterborne sewerage. Sewerage development can proceed independently where water supply conditions are adequate and can support waterborne sewerage.

The approach to phasing the treatment works and sewer network components in each urban centres will also depend on prevailing water supply conditions and the availability of spare treatment works capacity. The strategy for phasing of sewerage development for each urban centre is shown in the following table:

Urban Centre	Stage 1	Stage 2	Stage 3
Bungoma, Isiolo, Mombasa Condition A	Improve water supply	Extend Sewer Network	Expand sewage treatment works and/or build new
Kitale, Naivasha, Nyeri Condition B	Rehabilitate treatment works	Improve water supply	Expand sewage treatment works and sewer network
Kisii, Muranga, Nakuru, Webuye Condition C	Extend Sewer Network	Provide new sewage treatment works and/or expand existing	
Athi River, Kiambu Condition D	Extend Sewer Network		
Busia, Kericho, Homa Bay, Condition E	Provide new sewage treatment works and/or expand existing	Improve water supply	Extend Sewer Network
Eldoret, Embu, Kapsabet, Kisumu, Limuru, Kakamega, Machakos, Meru, Nairobi, Nanyuki, Ngong, Nyahururu, Thika Condition F	Provide new sewage treatment works and/or expand existing	Extend Sewer Network	
Garissa, Kabarnet, Kilifi, Malindi, Manderu, Maragua,Narok, Ongata, Ruiru, Voi, Wajir Condition G	Improve water supply	Provide Sewerage Network	

Note: improving water supply system is a constraint that must be resolve before the next stage can be implemented

Condition A = sewer network extensions are not possible due to low unit water consumption.

Condition B = existing treatment works can be rehabilitated but sewer network extensions are not possible due to low unit water consumption

Condition C = treatment works have capacity for more flow but will need expansion before 2010.

Condition D = treatment works have capacity for more flow but will not need expansion before 2010

Condition E = treatment plants are overloaded and should be expanded. Sewer network extensions are not possible due to low unit water consumption.

Condition F = treatment plants are overloaded and should be expanded before extending sewers.

Condition G = No existing sewer system.

4.5 Implementation and Disbursement Plan

(1) Implementation Schedule

To obtain the target of serving 38% of the urban population in 2010 with sewers, all the urban centre projects must be implemented in order of priority. The ranking is: Mombasa at first followed by Kisumu, Machakos, Narok, Malindi, etc. The ranking of the sewerage development priority in the urban centres is summarised in **Table - 4.5.1**.

In general, the sewer development projects must be co-ordinated with water supply schemes because the volume of sewage depends on that of water supply in the urban areas. In other words, the strategy for sewerage development should follow that of water supply development. Accordingly, the Study at first plans the implementation of water supply schemes as shown in **Table - 4.5.2**.

After programming water supply schemes, the implementation schedule for sewerage schemes is determined as shown in **Table - 4.5.3**. Some of the sewer schemes exceed the end of the planning horizon, because there are some water supply projects expected to be completed in the year 2010. The schedule consists of the following items:

1) Studies, surveys, detailed designs, financial arrangements, etc.
2) Rehabilitation of treatment works
3) New construction and rehabilitation of sewer reticulation
4) New construction and expansion of treatment works
5) New construction and expansion, rehabilitation of treatment works

(2) Disbursement Schedule

The disbursement of expenditures based on project cost estimates is planned in accordance with the implementation schedule. The costs of studies, surveys, detailed designs, financial arrangements, etc. are calculated by dividing total engineering costs equally into three years.

Table - 4.5.4 indicates the disbursement schedule from 1999 to 2011 for the complete programme, excluding deferred urban centres.

(3) Schedule based on Historical Funding Levels

The annualised costs of implementing the full sewerage development programme will likely exceed available financial resources. An alternate implementation plan (Schedule "B") was developed to provide annual costs that are closer to historical investment levels. The implementation schedule in **Table - 4.5.5** was developed by deleting lower priority projects. The corresponding disbursement schedule is shown in **Table - 4.5.6**.

CHAPTER 5 PRELIMINARY STUDY ON PRIORITY PROJECTS

5.1 Priority Projects

The implementation plan for achieving the proposed target service ratios by 2010 is based on the relative ranking of urban centres. It is clear that several projects share the same timeframe and will be competing for funding resources. Since funding will likely continue to be a serious constraint it is necessary to assess which projects should proceed on an urgent basis.

The selection of priority projects is made from the short list of the 9 urban centres identified in the implementation plan to start in the first year. The relative merits of sewerage development for each of these urban centres is evaluated against the following selection criteria and given an overall rating a shown below:

1) Expected health benefits and improvement to living conditions
2) Importance to the viability of tourism
3) Degree of sewerage development planning already in place
4) The present condition of existing sewerage systems
5) The status of on-going projects

Urban centre	Studies to date	Sanitation conditions	Status of on-going project	Health & environment benefits	Importance to viability of tourism	Overall rating
Mombasa	F/S	Contamination of drinking water supply, impact on reef and beaches	No funding commitment for design and construction	High	High	A
Nairobi	M/P	Good coverage except in slum areas, treatment plants performing well despite overload	World Bank actively involved	Medium	Low	C
Kisumu	F/S	Treatment works polluting Lake Victoria, high level of industrial pollutant.	JICA completing F/S, no funding identified for next phase	High	Medium	A
Machakos	M/P	Treatment works overloaded, polluting surface waters used for drinking.	No funding identified for next stage	High	Low	A
Meru	F/S	Adequate on-site sanitation is available. Existing sewage works is overloaded but capacity can be restored by removing sludge.	On-going water supply project will probably include sanitation improvements	Medium	Low	B
Nakuru	M/P and F/S	Treatment works are operating under design capacity	New treatment works recently completed but sewer reticulation required	High	Medium	C
Narok	nil	Wastewater drainage is affecting surface water used for drinking. On-site sanitation is inadequate.	No funding identified for sewerage development	High	High	A
Kitale	nil	Treatment works are operating under design capacity	GTZ is strengthening water management	Medium	Low	C
Malindi	M/P	On-site sanitation is inadequate.	No funding identified for sewerage development	High	High	A

A = Highest priority, B = intermediate priority, C = lower priority

Five priority urban centres (rating of A) are identified: Mombasa, Kisumu, Machakos, Malindi, and Narok. The project requirements for each urban centre are summarised below:

1) Mombasa: proceed to design and construction of facilities following the development programme proposed in feasibility study.
2) Kisumu: proceed to design and construction of facilities following the development programme proposed in feasibility study.
3) Machakos: pre-design review of existing master plan then proceed to design stage.
4) Malindi: proceed with design and construction as identified in master plan.
5) Narok: proceed with master plan and feasibility study to identify sewerage development plan.

5.2 Project Description

Master planning and feasibility studies are available for each urban centre except Narok. A summary of the proposed sewerage development from each master plan is provided below.

Mombasa
Source of information: (Draft feasibility study, Gibb Engineering Report, 1996)

"Currently only 10% of Mombasa's 600,000 population are connected to piped sewerage system. The main industries and hotels are not connected, and none of the municipality's treatment works are operating. Uncontrolled and untreated sewage is therefore being discharged into Mombasa's marine environment. This environment supports fragile and valuable ecosystems that include the offshore fringing coral reef, and a mangrove forest that exists within the inland creeks. It also supports a local fishing industry and a thriving tourism industry that contributes significantly to the National economy. Current levels of pollution are shown to be a threat to these industries and also to public health." The areas of Mombasa covered by sewerage are shown in **Figure - 5.2.1**.

A new treatment works is currently being completed on the West Mainland. The project included trunk sewers but not secondary sewer reticulation. The scope of the on-going project is shown in **Figure- 5.2.2**. Areas were prioritised during the strategy study for sewerage in accordance with their potential for reduction of pollution load, early maximisation of revenue, and household ability to pay for both the full costs of both water and sewerage. The resultant priority ranking was:

1) Mombasa Island primary and secondary sewer reticulation
2) The West Mainland secondary sewer reticulation
3) The North Mainland primary and secondary reticulation
4) The South Mainland primary and secondary reticulation

In accordance with these priorities a strategy for phased construction of the sewerage system was derived. The recommended staged construction project for the 2010 horizon is summarised below:

Stage	Period	Proposed Investments
1A	1997-2000	- North Mainland headworks and long sea outfall - Island trunk sewers, priority pumping stations, rising mains, - N. Mainland connecting sewers, M/E work
1B	2000-2010	- Island and W. Mainland secondary sewers and pumping stations

The scope of work of West Mainland is shown in **Figure - 5.2.3.**

In the feasibility study the system recommended for the Island and North Mainland includes "two main pumping stations on the Island, and a number of secondary pumping stations. Sewage will be collected at one of the main pumping stations, located close to Nyali Bridge and will be pumped across the bridge to a preliminary treatment plant prior to marine treatment and disposal via a long sea outfall. Alternative sewage treatment and disposal methods were evaluated. The proposed solution comprising preliminary treatment was the least cost solution designed to meet the water quality guidelines proposed. This option also presents the least risk in the case of plant or power failure."

Cost estimates from taken from the feasibility have been adjusted for inflation and included in the disbursement schedule for this study. Total project costs identified in the feasibility study are 3,426 million Kenyan shillings (approximately 57 million US dollars).

Kisumu
Source of information: (Draft Final Report, Kisumu Water Supply & Master Plan, JICA, 1998)

Currently approximately 56% of the population in Kisumu is connected to the wastewater system. The existing sewerage system is described in **Figure - 5.2.4.**

The central district collects wastewater from the area north-west of the old town by gravity and from low lying areas along lake Victoria through three pumping stations. All three pumping stations in the collection system are inoperative and wastewater overflows from manholes and pumping station wet wells to Lake Victoria. Flows are conveyed to a conventional treatment works that is overloaded hydraulically and organically. Flows exceed design capacity by more than 150% during dry weather and by more than 200% during the rainy season.

The eastern district collects wastewater from southeast of the old Kisumu town, and conveys it to a primary facultative pond facility. The treatment works receives less than 20% of its design capacity due to inadequate water supply in this district. As a result, sewers are blocked with sediment.

The master plan identifies that 60% of the wastewater flow from domestic and industrial sources should receive treatment by 2005. That percentage will increase to 83% in 2015. The proposed sewer area for 2015 is shown in **Figure - 5.2.5.** The priority project identified for the year 2005 consists of Phase 1 works identified as follows:

1) Rehabilitation of three pumping stations
2) Installation of 2.6 km of trunk sewers in central district and 23.1 km in eastern district

3) Rehabilitation of conventional treatment works (**Figure - 5.2.6**)
4) Expansion of conventional treatment works to 2015 design inflow
5) Rehabilitation of treatment ponds (**Figure - 5.2.7**)
Phase 1 costs total: 14,234,000

Phase 2 works are planned for the period 2005-2015 and consist of:

1) Construction of three new pumping stations
2) Abandon 1 existing pumping station
3) Expand existing ponds
4) Construct new treatment works in new western district (**Figure - 5.2.8**)
5) Provide 23.2 km of trunk sewers in new western district
Phase 2 costs total: 23,001,000

<u>Machakos</u>
Source of information: (Draft Final Report, Machakos Sewerage Scheme, Master Plan and Preliminary Design Report, Mangat, I.B. Patel & Partners, 1985)

Currently approximately 10% of the population in Machakos is connected to the wastewater system. The existing sewer network was originally installed in 1973. Since then a great deal of development has taken place. Most of this development is unsewered, which means wastewater is discharged untreated to receiving streams. The existing treatment facility is overloaded and is discharging poor quality effluent into the Mitheau river. This situation is creating a significant health risk in the area.

The municipality is divided into two areas north and south. The north consists of the northern slopes of the Mua hills and the Mitaboni plateau. In the 1985 study it was identified as rural and populations studies indicated it would remain so until middle of next century therefore no sewerage was proposed. The southern area is made up of land with the horseshoe ridge of hills. It contains the urban centre of Machakos town and the relatively flat land that surrounds it. This area is where most of the urban growth has occurred and where the sewerage system needs to be developed most urgently.

Drainage areas are shown on **Figure - 5.2.9**. The 1985 master plan identified development of sewer systems in two phases.

1) from 1985 to 1995 sewerage in drainage areas 2 & 3, and
2) from 1995 to 2005 sewerage in drainage area 4

The Phase 1 works identified in the 1985 master plan consist of:

1) upgrading sewers networks in drainage areas 2 & 3
2) new gravity trunk sewer lines A and F
3) new oxidation pond treatment facility at site 3 (Machakos)
4) new oxidation pond treatment facility at site 2 (Kiavndini)
5) New pumping station at Miwani river

Total costs 110,295,000 Kshs (1985 prices)

The Phase 2 works consist of:

1) New sewerage in drainage area 4
2) a new gravity sewer line B along the Maruba River
3) expansion of capacity @ t/w site 2 and 3
   Total costs 110,054,000 Kshs (1985 prices)

The population and land use projections made in the master plan should be compared to existing situation in order to confirm if phase two works should be implemented with Phase 1.

Malindi
Source of information: (Final Report, Malindi Sanitation and Hygiene Education Feasibility Study, Financed by Federal Republic of Germany, 1994)

Over 60% of the population in Malindi have no sanitation facilities at all. Over 40% of the population has no access to any direct source of water and there is clear evidence of shallow wells with nearby pit latrines. The potential for a major epidemic of cholera or typhoid is great. Malindi is an important tourism centre. Urgent action is necessary to ensure that the sanitation systems in the town are improved to sustain the welfare of the population and ensure further economic development.

The feasibility study proposes a sewerage system for densely developed parts of the town, hotels, commercial and industrial areas. The sewerage system consists of collector sewers, 3 pumping stations and a treatment facility all designed to meet the needs until 2005. The study evaluated several treatment site options and recommends the Ganda site. The feasibility study also recommends improving the collection of effluent from on-plot sanitation facilities in order to ensure a healthy living environment. A location plan is shown in **Figure - 5.2.10** and proposed sewer reticulation in **Figure - 5.2.11.** The treatment works layout is shown in **Figure - 5.2.12.**

Total project costs for sewerage is estimated at 580,000,000 Kshs (1994 prices).

Narok
At present, there are no sewer systems in Narok. According to the sewer development strategy, the number of the sewer served population is expected to reach 19,347 by the year 2010. Under the strategy sufficient sewer facilities and reticulation are required to cover Narok's served numbers as follows:

The development strategies of Narok from 1999 to 2011 are:

1) New treatment works: Waste Stabilisation Pond, and
2) New sewer reticulation: 22,055 m

The direct costs are:

1) New treatment works: 768,766 US$, and
2) New sewer reticulation: 1,336,694 US$

A preliminary layout of the waste stabilisation ponds is shown in **Figure - 5.2.13.**

- PART III : SEWERAGE DEVELOPMENT PLAN -

TABLES

Table - 1.1.1 Projects Identified in Public Investment Plan

On-going Project	Status	Estimated cost	Year started	Year of completion	Funding source
1) Kericho	3 rehabilitation complete	30,800	1991	2000	(FRG)
2) Kapsabet	3 new works completed	10,000	1990	2000	(not identified)
3) Nakuru	3 upgrade complete	250	1990	2000	(JAPAN)
4) Murang'a	3 new treatment works complete	92,500	1992	1998	(ADF)
5) Bungoma	2 construction halted	12,500	1992	1998	(ADF)
6) Nanyuki	3 rehabilitation complete	5,000	1991	2000	(GOK)
7) Meru	1 awaiting funding	72,000	1995	1998	(GOK)
8) Mombassa	2 new treatment works under construction	13,000	1988	2000	(GOK)
9) Kisii	2 new treatment works under construction	31,000	1990	2000	(ADF)
10) Vihigi	1 awaiting funding	500	1993	1998	(GOK)
11) Wajir	1 awaiting funding	300	1994	1998	(GOK)
12) Othaya	1 awaiting funding	400	1993	1998	(GOK)
13) Nyeri	1 awaiting funding	8,000	1990	2000	(GOK)
14) Embu	1 sewerage design complete	5,000	1992	2001	(GOK)
15) Machakos	1 master plan completed	500	1989	1998	(GOK)
16) Marsabit	1 awaiting funding	225	1994	2000	(GOK)
17) Karatina	3 improvements completed	500	1994	1999	(GOK)
18) Thika	1 master plan completed	750	1994	1999	(GOK)
19) Makueni	1 awaiting funding	not shown	not shown	not shown	(GOK)
20) Bomet	1 awaiting funding	400	1992	1997	(GOK)
21) Chuka	1 awaiting funding	750	1993	2000	(GOK)
21) Eldoret	1 design stage	900	1992	1999	(FRG)

Note: "1" under investigation, planning or design
"2" under implementatin
"3" under operation and maintenance

Legend : [ ] identified in DDP

Table - 1.1.2 Projects Identified in the District Development Plans

Urban Centre	Project Identified in District Development Plan	Status
1) Kiambu	Upgrade treatment works to double capacity	1
2) Kerugoya/Kutus	Water supply & sewerage to minimize water pollution	1
3) Kianyaga	Water supply & sewerage to minimize water pollution	1
4) Ol kalou	Construction of new sewerage system	1
5) Karatina	Sewer capacity improvements to relieve frequent blockages	3
6) Nyeri	Extend 4 trunk sewers & purchase vacuum truck for exhausting septic tanks	3
7) Malindi	Master plan for sewerage is complete, awaiting funding	1
8) Lamu	Septic tanks unsatisfactory, new sewerage system required for whole town.	1
9) Mwingi	Sewerage system required to reduce frequent outbreak of water borne disease	1
10) Embu	Sewerage design complete, awaiting funds	1
11) Meru	Provide sewerage system and relocate treatment works to larger site in Thuura	1
12) Isiolo	Complete house connection program started in '91	2
13) Chuka	Undertake water supply and sewerage works	1
14) Wajir	Provide sewerage system to replace the use of unsanitary bucket latrines	1
15) Keroka	Stabilization ponds designed but not implemented	1
16) Nyamira/Kebirigo	On-site systems are unsatisfactory; provide sewerage system	1
17) Kisumu	Expansion of water supply and sewerage facilities	1
18) Homa Bay	Rehabilitation of treatment works	1
19) Kehancha	Construction of sewerage network and treatment works	1
20) Nyabikaye	Construction of sewerage network and treatment works	1
21) Kilgoris	Construction of sewerage network and treatment works	1
22) Kabarnet	On-site sanitation is unsatisfactory; planning & design for construction of sewerage network and treatment works.	1
23) Marigat	Planning for sewerage is required	1
24) Webuye	Extend sewerage to include schools and hospital	1
25) Kapsakwony	Construct a new sewerage system	1
26) Busia	Construct a new sewerage treatment works	1
27) Luanda	Construct a new sewage treatment works to allow hygienic disposal of sanitary waste	1
28) Kakamega	De-sludging of ponds	1
29) Kapsabet/Baraton	Complete ph2 of sewerage, piping and pump installations	2

Note: "1" under investigation, planning or design
"2" under implementatin
"3" under operation and maintenance

Legend : [ ] identified in PIP

Table - 2.1.1 Summary of Sewage Disposal Methods in Kenya

Census Data				Welfare Monitoring Report '94 [2]		
Method of disposal	% of Total Population		% of Urban Population	% of Total Population	% of Urban Population	Method of disposal
	'69[1]	'89	'89			
Public Sewerage	2	6.7	28.7	4.5	20.5	Water Closet
				4.6	20.8	Pour Flush
				9.1	41.3	sub-total (includes septic tanks)
Pit Latrine	40	68.5	57.0	68.6	50.7	Pit Latrine
				2.5	5.0	V.I.P.
				71.1	55.7	sub-total
Other (mainly septic tank)	7	4.7	10.7	0.2	0.5	Bucket
No sanitation (mainly bush)	51	20.1	3.6	19.6	2.4	No Sanitation

Source: (1) Figures taken from WHO report no. 8 (1972), (2) Central Bureau of Statisitics

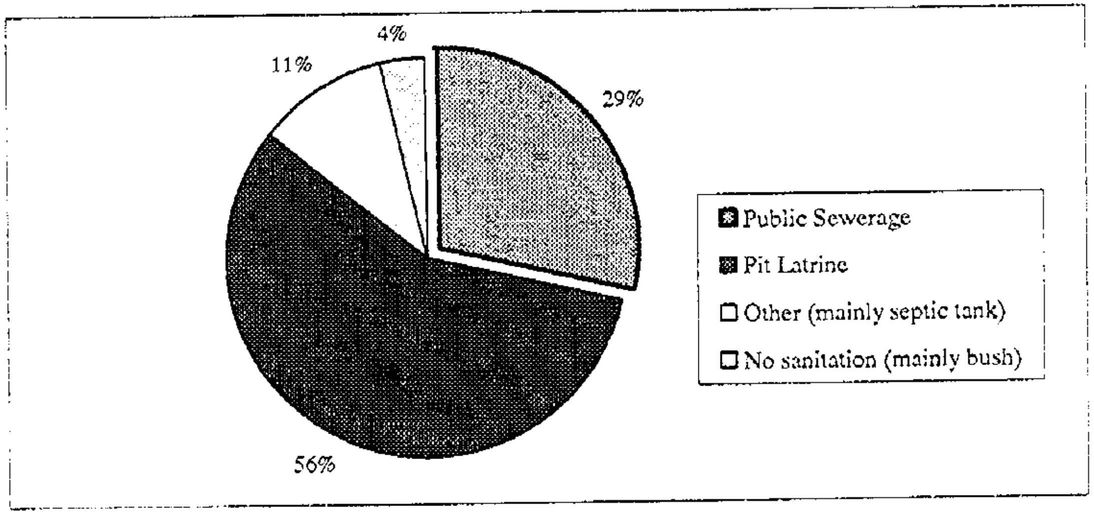


Table - 2.2.1 (1/4) Summary of Urban Sewerage Schemes

No.	District	Urban Area / Name of Scheme	Municipal Area (km^2)	Urban Population	Quantity of Water Supplied (m^3/d)	Water Undertaker	Type of Sewage Treatment Works	Year Constructed (Expansion)	Treatment Works Capacity (m^3/d)	Organization Running the Works	No. of Sewer Connections	Population Served	Present Flow (m^3/d)	Per capita flow (lpcd)	Total Length of Sewers (m)	Length per capita (m)	Method of Sludge Treatment	Influent BOD (mg/l)	Per capita BOD (g/day)	Effluent BOD (mg/l)	Total O & M Staff	Remarks
1	Bungoma	Bungoma	55	70,000	2,620	NWCPC	WSP	1965	45	Municipal Council	260	12,600	NFM		3,710	0.29	No Facility	550	NFM	No Effluent	9	- The works have been neglected. The first pond is full of sludge and covered with vegetation. Part o The plot is being used as a school. - No Effluent from The first pond. - Construction of the newworks has been stopped. - Future plans to complete stalled sewerage project
2	Kisumu	Kisumu (conventional)	390 ha	231,687	14,565	NWCPC	conventional	1966, subsequent rehabilitation in 1986	6,800	Municipal Council	NA	130,000	13,000	115	8,500	0.13	anaerobic digestion followed by sludge drying beds	822-914	105	143-254	NA	- oil separator unit added in 1986 is not working, frequent mechanical and electrical equipment failures, the treatment works are subjected to heavy organic and hydraulic overload.
3	Kisumu	Nyalenda	214 ha				WSP	1975	11,000				2,000		8,000		No Facility	314-472	54	75-86		heavy accumulation of weeds and sludge has reduced hydraulic retention times
4	Nakuru	Nakuru town	4.2	123,500	41,120	Municipal Council	WSP	1997	6,600	Municipal Council	NA	57,480	3,484	61	86,156	0.70	anaerobic digestion followed by sludge drying beds	875	53	104	60	- new t/w - operating below capacity
5	Nakuru	Nakuru - Njoro	8.7				WSP	1997	9,600			65,980	4,739	72				665	48	236		- new t/w - operating below capacity
6	Meru	Meru	NA	124,412	4,700	MOWR	WSP	1974	2,500	Municipal Council	NA	800	500	625	NA	NA	No Facility	502	314	160	NA	- hydraulically overloaded - no screening or grit removal - no maintenance
7	Isiolo	Isiolo	NA	124,412	4,700	MOWR	WSP	1984	2,000	Municipal Council	NA	1,700	595	350	NA	NA	No Facility	605	212	251	NA	- accumulation of sludge - poorly maintained, no grass cutting, weeds
8	Nyeri	Karatina	NA	7,299	1,300	MOWR	WSP	NA	317	Municipal Council	NA	5,109	561	116	NA	NA	No Facility	267-438	51	23-63	NA	- t/w slightly overloaded
9	Bungoma	Webuye	69	60,000	1,700	NWCPC	WSP	1973	NA	Municipal Council	1,620	12,000	NFM	NFM	8,500	0.71	No Facility	200	NFM	60	9	- There is no inlet works and the ponds are choked with sludge. - No access road to site. - About 40% of the sewer lines are undersize (< 150mm) - No future plans for rehabilitation or expansion
10	Busia	Busia (South Teso)	25	48,000	2,072	NWCPC	WSP	1981	600	Municipal Council	473	9,600	600	63	7,350	0.77	No Facility	200	13	85	13	- The works are poorly maintained - Seepage from embankment between first and third pond. - Slabs lining the second maturation pond have collapsed. - No future plans for rehabilitation or expansion.
11	Embu	Embu	80	45,000	7,305	NWCPC	WSP	1973	682	Municipal Council	1,400	9,000	NFM	NFM	13,395	1.49	No Facility	700	NFM	140	7	- The works are overloaded and poorly maintained - Sludge accumulation in the facultative pond. - Future plans for rehabilitation and expansion of treatment works and sewer system. (awaiting funding)

Table - 2.2.1 (2/4) Summary of Urban Sewerage Schemes

No.	District	Urban Area / Name of Scheme	Municipal Area (km^2)	Urban Population	Quantity of Water Supplied (m^3/d)	Water Undertaker	Type of Sewage Treatment Works	Year Constructed (Expansion)	Treatment Works Capacity (m^3/d)	Organization Running the Works	No. of Sewer Connections	Population Served	Present Flow (m^3/d)	Per capita flow (lpcd)	Total Length of Sewers (m)	Length per capita (m)	Method of Sludge Treatment	Influent BOD (mg/l)	Per capita BOD (g/day)	Effluent BOD (mg/l)	Total O & M Staff	Remarks
12	Kajiado	Ngong	NA	15,000	1,260	NWCPC	WSP	1950s	230	Municipal Council	85	750	NFM	NFM	NA	NA	No Facility	Inlet Not Accessible	NFM	No Effluent	2	- the works have been neglected and ponds are covered with vegetation. - There is very little flow to the works and the second pond is dry - no future plans for rehabilitation or expansion
13	Kakamega	Kakamega - Kambi Somali	51	110,000	7,000	NWCPC	WSP	1980	NA	Municipal Council	500	51,700	500	97	3,455	0.07	No Facility	300	29	No Effluent	11	- The works have been neglected and ponds are covered with vegetation. - There is very little flow to the works and there is no effluent to the river. - No future plans for rehabilitation or expansion
14	Kakamega	Kakamega - Shirere					WSP	1972	NA		5,000		4,500				No Facility	500	48	50		- the works have been neglected and ponds are covered with vegetation and require desludging - There is very little flow to the works and no flow to the last pond, surface water runoff to ponds - no future plans for rehabilitation or expansion
15	Kericho	Kericho	66	80,000	5,246	Municipal Council	Conventional	1962 (1995)	1,500	Municipal Council	236	41,600	2,000	48	15,625	0.38	Digesters & Drying	450	22	25	30	- existing t/w rehabilitated and expanded - very well maintained
16	Kiambu	Kiambu	58	7,500	490	Municipal Council	Conventional	1982	960	Municipal Council	127	2,250	NFM	NFM	NA	NA	Drying	225	NFM	90	7	- Well maintained works. - There is provision to increase the capacity of the works. However, there is no space for polishing ponds. - Future planned expansion of treatment works.
17	Kiambu	Limuru	NA	3,000	660	NWCPC	Conventional	1984	550	NWCPC	352	2,100	NFM	NFM	7,725	3.68	Drying	90	NFM	68	6	- Mechanical equipment on site does not function. - The maturation pond and sludge drying beds are covered with vegetation. - The works are poorly maintained. - No future plans for rehabilitation or expansion.
18	Kiambu	Thika	93	155,770	24,000	Municipal Council	WSP	1972	6,100	Municipal Council	6,000	87,230	10,000	115	18,740	0.21	No facility	570	65	40	30	- The works are overloaded and poorly maintained. - Mechanical equipment at inlet works does not function. - Sewer blockages are common due to small size pipes. - Masterplan proposals (funding agency being sought)
19	Kisii	Kisii	29	65,000	4,000	NWCPC	WSP	To be commissioned	NA	Municipal Council	500	13,000	NFM	NFM	NA	NA	Drying	500	NFM	No Effluent	8	- Newly constructed Treatment Works still filling. - Old Treatment Works have been abandoned.
20	Laikipia	Nanyuki	147	55,000	11,250	Municipal Council	WSP	1985	2,270	Municipal Council	2,100	24,750	8,000	323	33,880	1.37	No Facility	294	95	68	15	- The works are not well maintained. - Some concrete sewer pipes have ingrown roots. - No future plans for rehabilitation or expansion.
21	Laikipia	Nyahururu	104	60,000	3,000	Municipal Council	Conventional	1987	2,500	Municipal Council	1,511	18,000	3,436	191	23,385	1.30	No Facility	300	57	50	20	- The works are well maintained. - Inadequate power supply to run both aerators at the same time. - Future planned expansion of treatment works and sewer system.
22	Machakos	Muvuti - Machakos	520	80,000	1,740	NWCPC	WSP	1974 (1984)	2,000	Municipal Council	2,000	8,000	NFM	NFM	18,070	2.26	No Facility	670	NFM	130	18	- The works are overloaded and anaerobic pond requires desludging. - Maturation pond is formed by a dam across the stream and is overgrown with weeds. - The works are not well maintained. - Masterplan proposal (funding agency being sought)
23	Machakos	Mavoko (Athi River)	684	50,000	2,000	NWCPC / NCC	WSP	1994	12,960	Municipal Council	370	12,500	NFM	NFM	22,070	1.77	No Facility	Site Not Accessible	NFM	Site Not Accessible	10	- Low flow to the new works and ponds are still filling. - The works are poorly maintained. - Pump station is not currently being used due to broken sewer line. - No future planned rehabilitaion or expansion.

Table - 2.2.1 (3/4) Summary of Urban Sewerage Schemes

No.	District	Urban Area / Name of Scheme	Municipal Area (km^2)	Urban Population	Quantity of Water Supplied (m^3/d)	Water Undertaker	Type of Sewage Treatment Works	Year Constructed (Expansion)	Treatment Works Capacity (m^3/d)	Organization Running the Works	No. of Sewer Connections	Population Served	Present Flow (m^3/d)	Per capita flow (lpcd)	Total Length of Sewers (m)	Length per capita (m)	Method of Sludge Treatment	Influent BOD (mg/l)	Per capita BOD (g/day)	Effluent BOD (mg/l)	Total O & M Staff	Remarks
24	Mombasa	Mombasa - Changamwe	282	580,000	180,200	NWCPC	Conventional	1961	17,100	Municipal Council	NA	69,600	1,450	66	9,400	0.14	Drying	NA	NA	NA		- New works still to be commissioned and old works to be abandoned.
25	Mombasa	Mombasa - Kizingo					Primary Sedimentation	1961	32,500		NA		3,140		22,970		No Facility	NA	NA	NA		- Treatment works has not worked since 1988 and raw sewage passes to the sea. - Mechanical equipment on site does not function. - Proposed long sea outfall.
26	Muranga	Mbiri - Muranga	25	30,000	2,000	MOWR	WSP	1997	1,564	Municipal Council	500	10,500	870	83	14,645	1.39	No Facility	568	47	50	17	- Newly constructed Treatment Works receives low flow. Levels in the ponds made up with river water.
27	Nairobi	Nairobi - Dandora	693	2,240,000	326,700	NWCPC	WSP	1977 (1992)	80,000	Nairobi City Council	NA	1,000,000	Estimate 217,000	217	153,000	0.15	No Facility	440	95	120	60	- The works are well maintained and the old ponds are being desludged. - Future planned construction of new anaerobic ponds.
28	Nairobi	Nairobi - Kariobangi					Conventional	1961	32,000	Nairobi City Council							Digester & Drying	448		129		- The works are not well maintained. - Some mechanical equipment does not function. - The works are overloaded and there is no space for polishing ponds. - No future planned rehabilitation or expansion.
29	Nakuru	Naivasha	9.89	60,000	762	NWCPC	Conventional	1983	2,035	Municipal Council	2,012	30,000	NFM	NFM	15,640	0.52	Sludge Thickener & Drying	664	NFM	60	11	- Mechanical equipment on site has not functioned since 1992. - Aerated lagoons and facultative pond require desludging. - Future planned rehabilitation of treatment works (Electomechanical equipment)
30	Nandi	Kapsabet	14	20,000	1,100	NWCPC	WSP	1997	1,000	Municipal Council	130	4,000	NFM	NFM	35,540	8.89	No Facility	480	NFM	20	8	- Newly constructed Treatment Works to be commissioned and is well maintained
31	Nyeri	Nyeri - Kiganjo	200	22,000	7,000	Municipal Council	WSP	1990	2,000	Municipal Council	73	1,100	500	455	5,885	5.35	Drying	560	255	185	7	- Inflow is low due to few sewer connections and frequent breakdown of the pumping station. - Sludge drying beds have never been used due to low flow and are flooded. - No future plans for rehabilitation or expansion
32	Nyeri	Nyeri - ADB		120,000			Conventional	1988	6,100	Municipal Council	1,865	36,000	2,000	56	42,540	1.18	Digester & Drying	372	21	87	23	- Grit removal air blowers and flow recorder out of order. - Third maturation pond embankment washed away and sludge drying beds flooded. - Trunk sewer damaged and some sewage leaking. - Planned rehabilitation of trunk sewer and maturation pond.
33	Taita	Voi	16	15,772	2,700	NWCPC	WSP	1980	NA	Municipal Council	NA	700	Facility is dry	NFM	NA	NA	No Facility	NA	NA	NFM	NA	- no flow to pond - pond is dry
34	South Nyanza	Homa Bay	197	75,000	1,231	NWCPC	Conventional	1987	750	Municipal Council	2,500	15,000	1,045	70	9,650	0.64	Sludge Thickener & Drying	250	17	40	11	- Mechanical equipment on site does not function. - Sedimentation tanks are by-passed due to sludge accumulation. - Surface water run-off to ponds. - The works are poorly maintained. - No future plans for rehabilitation oe expansion.

Table - 2.2.1 (4/4) Summary of Urban Sewerage Schemes

No.	District	Urban Area / Name of Scheme	Municipal Area (km^2)	Urban Population	Quantity of Water Supplied (m^3/d)	Water Undertaker	Type of Sewage Treatment Works	Year Constructed (Expansion)	Treatment Works Capacity (m^3/d)	Organization Running the Works	No. of Sewer Connections	Population Served	Present Flow (m^3/d)	Per capita flow (lpcd)	Total Length of Sewers (m)	Length per capita (m)	Method of Sludge Treatment	Influent BOD (mg/l)	Per capita BOD (g/day)	Effluent BOD (mg/l)	Total O & M Staff	Remarks
35	Trans Nzoia	Kitale - Conventional	92	75,000	9,000	Municipal Council	Conventional	1957 (1978)	1,830	Municipal Council	1,500	37,500	NFM	NFM	54,945	1.47	No Facility	550	NFM	105	9	- Mechanical equipment on site does not function and most of the units are blocked. - The works receive negligible wastewater and are poorly maintained. - No future planned rehabilitation or expansion.
36	Trans Nzoia	Kitale - Ponds					WSP	1983	2,930				NFM				Drying	550	NFM	100		- The works are well maintained but receive high strength industrial waste. - No future planned rehabilitation or expansion.
37	Uasin Gishu	Eldoret - Conventional	147	220,000	25,000	Municipal Council	Conventional	1959	1,575	Municipal Council	5,886	70,400	6,000	NFM	21,900	0.31	Digester & Drying	300		115	38	- The works are overloaded. Overflow is diverted to the waste stabilization ponds site. - The works are well maintained. However, some mechanical parts require replacing. - Future planned construction of new treatment works.
38	Uasin Gishu	Eldoret - Ponds					WSP	1978	4,800				NFM				No Facility	370		85		- The works are overloaded and receive a lot of industrial waste. There is permanent overflow to the facultative pond. - Anaerobic ponds require desludging. - Future planned construction of new treatment works.

Note: Legend

WSP	- Waste stabilization ponds
NWCPC	- National Water Conservation & Pipeline Corporation
NCC	- Nairobi City Council
NFM	- No flow measurement
NA	- Not available

Table - 2.2.2 Comparison between Sewage Quantities and Water Supplied

					Sewerage Developement 1998					Water Supply Conditions 1998			
							Present Sewage Flow				Quantity of Water Supplied		
	Province	District	Urban Centre	Urban Population	Population connected to sewer	Service coverage ratio	Treatment Works Capacity m3/day	m3/day	Liters per Capita/day	Population connected to water supply	m3/day	Liters per Capita/day	Service coverage ratio
1	Nairobi	Nairobi	Nairobi	2,240,000	1,000,000	45%	112,000	217,000	217	1,784,577	364,000	163	80%
2	Coast	Mombasa	Mombasa	580,000	69,600	12%	49,600	4,590	66	370,764	18,200	49	64%
3	Rift Valley	Nakuru	Nakuru	231,687	123,500	53%	16,200	8,181	66	304,561	41,120	135	131%
4	Nyanza	Kisumu	Kisumu	231,327	130,000	56%	17,800	15,000	115	280,845	14,565	52	121%
5	Rift Valley	Uasin Gishu	Eldoret	220,000	70,400	32%	6,375	NFM		90,000	28,850	321	41%
6	Central	Kiambu	Thika	155,770	87,230	56%	6,100	10,000	115	120,000	24,000	200	77%
7	Central	Nyeri	Nyeri	142,000	37,100	26%	8,100	2,500	67	40,000	5,940	149	28%
8	Eastern	Meru	Meru	124,412	800	1%	2,500	500	625	16,330	4,730	290	13%
9	Western	Kakamega	Kakamega	110,000	51,700	47%	5,500	4,800	93	27,826	7,000	252	25%
10	Rift Valley	Kericho	Kericho	80,000	41,600	52%	1,500	2,000	48	58,723	5,325	91	73%
11	Eastern	Machakos	Machakos	80,000	8,000	10%	2,000	3,000	375	80,000	2,660	33	100%
12	Rift Valley	Trans Nzoia	Kitale	75,000	37,500	50%	2,930	NFM		60,000	9,000	150	80%
13	Nyanza	Homa Bay	Homa Bay	75,000	15,000	20%	750	1,045	70	43,000	1,231	29	57%
14	Western	Bungoma	Bungoma	70,000	12,600	18%	45	NFM		36,000	2,620	73	51%
15	Nyanza	Kisii	Kisii	65,000	13,000	20%	NA	NFM		45,000	3,520	78	69%
16	Rift Valley	Nakuru	Naivasha	60,000	30,000	50%	2,035	700	23	46,000	762	17	77%
17	Rift Valley	Laikipia	Nyahururu	60,000	18,000	30%	2,500	3,436	191	50,000	3,000	60	83%
18	Western	Bungoma	Webuye	60,000	12,000	20%	NA	1,500	125	40,000	1,700	43	67%
19	Rift Valley	Laikipia	Nanyuki	55,000	24,750	45%	2,270	8,000	323	43,100	2,720	63	78%
20	Eastern	Machakos	Athi River	50,000	12,500	25%	12,960	1,000	80	12,500	2,000	160	25%
21	Coast	Kilifi	Malindi	48,227	0	0%	0	0	0	141,293	15,985	113	293%
22	Western	Busia	Busia	48,000	9,600	20%	600	600	63	17,267	2,072	120	36%
23	Eastern	Embu	Embu	45,000	9,000	20%	682	835	93	35,000	4,058	116	78%
24	North Eastern	Garissa	Garissa	40,000	0	0%	0	0	0	34,758	1,440	41	87%
25	Central	Muranga	Maragua	39,411	0	0%	0	0	0	6,200	15	2	16%
26	Central	Kiambu	Ruiru	32,302	0	0%	0	0	0	6,000	781	130	19%
27	Central	Muranga	Muranga	30,000	10,500	35%	1,564	870	83	24,000	2,000	83	80%
28	Eastern	Isiolo	Isiolo	26,968	1,700	6%	2,000	600	353	36,000	4,356	121	133%
29	North Eastern	Wajir	Wajir	26,239	0	0%	0	0	0	1,500	20	13	6%
30	Rift Valley	Kajiado	Ongata Longai	25,080	0	0%	0	0	0	7,200	978	136	29%
31	North Eastern	Mandera	Mandera	22,856	0	0%	0	0	0	8,160	500	61	36%
32	Coast	Kilifi	Kilifi	20,555	0	0%	0	0	0	30,170	4,300	143	147%
33	Rift Valley	Nandi	Kapsabet + Baraton	20,000	4,000	20%	1,000	NFM		7,000	1,100	157	35%
34	Rift Valley	Narok	Narok	19,859	0	0%	0	0	0	12,000	1,315	110	60%
35	Coast	Taita Taveta	Voi	15,772	700	4%	0	0	0	20,300	2,700	133	129%
36	Rift Valley	Kajiado	Ngong	15,000	750	5%	230	NFM		6,000	1,260	210	40%
37	Rift Valley	Baringo	Kabarnet	11,804	0	0%	0	0	0	127,500	2,042	16	1080%
38	Central	Kiambu	Kiambu	7,500	2,250	30%	960	300	133	8,058	490	61	107%
39	Central	Nyeri	Karatina	7,299	5,109	70%	317	561	110	14,533	1,300	89	199%
40	Central	Kiambu	Limuru	3,000	2,100	70%	550			1,958	1,538	785	65%

Table - 2.2.3 Effluent Standard

"A"- Acceptance into Public Sewers	
B.O.D (5 days at 20°C)	Not to exceed 450 mg/l
pH	To be in the range 6 to 9.
Temperature	Not to exceed 35°C
Suspended Solid	Not to exceed 300 mg/l
4 hours oxygen absorption for permanganate	N./80 at 27°C, 100 mg/l
Greases	The wastes should not (contain more than 100 milligrams per litter of greases that dissolve in Ethyl-ether.
Oil, Petrol, Kerosene or other combustible materials	These must be intercepted.
TOXICITY	The wastes should not include any toxic materials.

Note: 1) In addition the waste should not contain materials that might damage pipes or treatment works.

2) The flow must not exceed the capacity of the sewerage system and a meter is to be provided with a log book to record flows which can be inspected by the City Engineer or Medical Officer of Health.

2) Quarterly tests will be carried out, at the expense of the industry concerned, in accordance with the "Standard Methods for the Examination of water, sewage and Industrial wastes", issued by the American Public Health Association.

"B" - Direct Discharge to Natural Water Course	
C.O.D	Not to exceed 10 mg/l
Total Nitrogen exclusive NO	1 mg/l
NH_3	1.5 mg/l
B.O.D (5 days at 20°C)	Not to exceed 20 mg/l
pH	In the range 6 to 9
Temperature	Not to exceed 25°C
Suspended solids	Not to exceed 30 mg/l
Total Dissolved Solids	Not to exceed 1,500 mg/l
4 hours oxygen absorption for permanganate	N./80 at 27°C not to exceed 15 m/gl.
Nitrate as NO_3	Not to exceed 45 mg/l

Note: All other standards mention in "A" supra viz. greases oil toxic materials also apply.

Table - 2.2.4 (1/4) Results of Wastewater Quality Testing

Suspended Solid

No.	Urban Name/Plant	Influent (mg/l)	Effluent (mg/l)	% Removal	River		Ratio	
					Upstream	Downstream	U.Stream /D.Stream	Effluent /D. Stream
1	Bungoma	700	400	42.86	–	–	–	–
2	Webuye	80	67	16.25	20	20	1.00	3.35
3	Busia	60	20	66.67	20	20	1.00	1.00
4	Embu	900	410	54.44	810	825	0.98	0.50
5	Kakamega Kambi Somali	200	–	–	–	–	–	–
6	Kakamega Shirere Ponds	200	20	90.00	60	90	0.67	0.22
7	Kericho	250	60	76.00	–	–	–	–
8	Kiambu	905	280	69.06	580	590	0.98	0.47
9	Limuru	1,170	670	42.74	–	1,050	–	0.64
10	Thika	1,900	1,170	38.42	1,000	1,050	0.95	1.11
11	Kisii (Old Ponds)	40	–	–	100	275	0.36	–
12	Nanyuki	280	75	73.21	530	440	1.20	0.17
13	Nyahururu	1,515	920	39.27	1,500	–	–	–
14	Machakos (Mavuti)	1,265	685	45.85	1,201	1,235	0.97	0.55
15	Mavoko (Athi River)	–	–	–	–	–	–	–
16	Mbiri (Muranga)	800	60	92.50	6	10	0.60	6.00
17	Nairobi (Dandora)	1,405	570	59.43	1,630	1,825	0.89	0.31
18	Nairobi (Kariobangi)	1,800	1,160	35.56	1,225	1,325	0.92	0.88
19	Naivasha	630	180	71.43	–	–	–	–
20	Kapsabet	140	80	42.86	–	30	–	2.67
21	Nyeri (Kiganjo)	1,000	200	80.00	1,160	1,325	0.88	0.15
22	Nyeri (ADB)	1,050	760	27.62	1,153	1,124	1.03	0.68
23	Homa Bay	400	40	90.00	–	–	–	–
24	Voi	–	–	–	–	–	–	–
25	Kitale Conventional	700	40	94.29	25	167	0.15	0.24
26	Kitale Ponds	11,700	700	–	–	–	–	–
27	Eldoret Conventional	140	20	85.71	10	50	0.20	0.40
28	Eldoret Ponds	800	650	18.75	240	250	0.96	2.60
29	Isiolo (1)	653	170	73.97	–	–		–
30	Meru (1)	621	197	68.28	–	–		–
31	Nakuru Njoro (2)	566	93	83.57	–	–		–
32	Nakuru Town (2)	315	56	82.22	–	–		–
33	Kisumu (Conventional)	864	579	32.99	–	–		–
34	Kisumu Ponds - Nyalenda (3)	893	197	77.94	–	–		–
	Average	718	351	61.10				
	Maximum	1,900	1,170	94.29	1,500	1,825		
	Minimum	40	20	16.25	6	10		

Source: (1) JICA Report 1997 " The Study on the Water Supply for Seven Towns in Kenya"
(2) JICA Report 1994 " Feasibility Study on the Nakuru Sewege Works Rehabilitation and Expansion Project"
(3)JICA Report 1997 " On-going Study on Kisumu Water Supply and Sewerage System"

Table - 2.2.4 (2/4) Results of Wastewater Quality Testing

BOD

No.	Urban Name/Plant	Influent (mg/l)	Effluent (mg/l)	% Removal	River		Ratio		Influent Ratio BOD/COD
					Upstream	Downstream	U.Stream /D.Stream	Effluent /D. Stream	
1	Bungoma	550	12.5	97.73	-	-	-	-	-
2	Webuye	200	60	70.00	10.5	7.5	1.40	8.00	0.29
3	Busia	200	85	57.50	12.5	8.5	1.47	10.00	0.71
4	Embu	700	140	80.00	55	44	1.25	3.18	0.64
5	Kakamega Kambi Somali	300	-	-	-	-	-	-	0.30
6	Kakamega Shirere Ponds	500	50	90.00	7.5	5	1.50	10.00	-
7	Kericho	450	25	94.44	-	-	-	-	0.23
8	Kiambu	225	90	60.00	16	10	1.60	9.00	0.32
9	Limuru	90	68	24.44	-	13	-	5.23	-
10	Thika	570	40	92.98	20	20	1.00	2.00	0.71
11	Kisii (Old Ponds)	500	-	-	6.5	4	1.63	-	0.25
12	Nanyuki	294	68	76.87	30	30	1.00	2.27	0.45
13	Nyahururu	300	50	83.33	30	-	-	-	0.38
14	Machakos (Mavuti)	670	130	80.60	40	50	0.80	2.60	0.56
15	Mavoko (Athi River)	-	-	-	-	-	-	-	-
16	Mbiri (Muranga)	568	50	91.20	16	16	1.00	3.13	0.36
17	Nairobi (Dandora)	440	120	72.73	46	43	1.07	2.79	0.55
18	Nairobi (Kariobangi)	448	129	71.21	54	112	0.48	1.15	0.56
19	Naivasha	664	60	90.96	-	-	-	-	0.33
20	Kapsabet	480	20	95.83	-	4	-	5.00	0.60
21	Nyeri (Kiganjo)	560	185	66.96	20	10	2.00	18.50	0.51
22	Nyeri (ADB)	372	87	76.61	21	23	0.91	3.78	0.41
23	Homa Bay	250	40	84.00	-	-	-	-	0.37
24	Voi	-	-	-	-	-	-	-	-
25	Kitale Conventional	550	100	81.82	12.5	9.5	1.32	10.53	0.16
26	Kitale Ponds	550	105	80.91	-	-	-	-	0.01
27	Eldoret Conventional	300	115	61.67	12.5	5	2.50	23.00	0.38
28	Eldoret Ponds	370	85	77.03	10.5	4	2.63	92.50	0.55
29	Isiolo (1)	605	251	58.51	-	-	-	-	-
30	Meru (1)	502	160	68.13	-	-	-	-	-
31	Nakuru Njoro (2)	665	236	64.51	-	-	-	-	0.82
32	Nakuru Town (2)	875	104	88.11	-	-	-	-	0.82
33	Kisumu (Conventional)	868	216	75.12	-	-	-	-	0.34
34	Kisumu Ponds - Nyalenda (3)	374	79	78.88	-	-	-	-	0.38
	Average	480.64	98.68	76.40					
	Maximum	875	460	97.00	54	112			
	Minimum	200	12.5	24.44	6.5	4			

Source:
(1) JICA Report 1997 " The Study on the Water Supply for Seven Towns in Kenya"
(2) JICA Report 1994 " Feasibility Study on the Nakuru Sewege Works Rehabilitation and Expansion Project"
(3)JICA Report 1997 " On-going Study on Kisumu Water Supply and Sewerage System"

Table - 2.2.4 (3/4) Results of Wastewater Quality Testing

COD

No.	Urban Name/Plant	Influent (mg/l)	Effluent (mg/l)	% Removal	River		Ratio	
					Upstream	Downstream	U.Stream /D.Stream	Effluent /D.Stream
1	Bungoma	-	-	-	-	-	-	-
2	Webuye	700	100	85.71	57	70	0.81	1.43
3	Busia	280	105	62.50	40	85	0.47	1.24
4	Embu	1,100	240	78.18	100	100	1.00	2.40
5	Kakamega Kambi Somali	1,000	-	-	-	-	-	-
6	Kakamega Shirere Ponds	-	100	-	45	55	0.82	1.82
7	Kericho	1,950	120	93.85	-	-	-	-
8	Kiambu	700	300	57.14	50	50	1.00	6.00
9	Limuru	-	-	-	-	-	-	-
10	Thika	800	120	85.00	80	80	1.00	1.50
11	Kisii (Old Ponds)	2,000	-	-	40	45	0.89	-
12	Nanyuki	650	140	78.46	60	60	1.00	2.33
13	Nyahururu	800	120	85.00	60	-	-	-
14	Machakos (Mavuti)	1,200	300	75.00	70	100	0.70	3.00
15	Mavoko (Athi River)	-	-	-	-	-	-	-
16	Mbiri (Muranga)	1,600	200	87.50	20	20	1.00	10.00
17	Nairobi (Dandora)	800	320	60.00	160	160	1.00	2.00
18	Nairobi (Kariobangi)	800	180	77.50	120	280	0.43	0.64
19	Naivasha	2,000	100	95.00	-	-	-	-
20	Kapsabet	800	220	72.50	-	-	-	-
21	Nyeri (Kiganjo)	1,100	350	68.18	40	40	1.00	8.75
22	Nyeri (ADB)	900	450	50.00	40	40	1.00	11.25
23	Homa Bay	675	168	75.11	-	-	-	-
24	Voi	-	-	-	-	-	-	-
25	Kitale Conventional	3,520	120	96.59	90	85	1.06	1.41
26	Kitale Ponds	63,500	180	99.72	-	-	-	-
27	Eldoret Conventional	800	80	90.00	35	41	0.85	1.95
28	Eldoret Ponds	670	296	55.82	40	40	1.00	7.40
29	Isiolo (1)	-	-	-	-	-	-	-
30	Meru (1)	-	-	-	-	-	-	-
31	Nakuru Njoro (2)	810	290	64.20	-	-	-	-
32	Nakuru Town (2)	1,070	172	83.93	-	-	-	-
33	Kisumu (Conventional)	2,550	633	75.18	-	-	-	-
34	Kisumu Ponds - Nyalenda (3)	978	354	63.80	-	-	-	-
	Average	1,163.58	223.12	75.67				
	Maximum	3520	633	96.50	160	280		
	Minimum	280	80	55.80	20	20		

Source :

(1) JICA Report 1997 " The Study on the Water Supply for Seven Towns in Kenya"

(2) JICA Report 1994 " Feasibility Study on the Nakuru Sewege Works Rehabilitation and Expansion Project"

(3)JICA Report 1997 " On-going Study on Kisumu Water Supply and Sewerage System"

Table - 2.2.4 (4/4) Results of Wastewater Quality Testing

DO,T-N

No.	Urban Name/Plant	Effluent DO (mg/l)	Effluent T-N (mg/l)	DO River D.Stream (mg/l)	DO River U.Stream (mg/l)
1	Bungoma	-	-	-	-
2	Webuye	6	14.8	6.00	5.9
3	Busia	8.5	14.4	6.00	5
4	Embu	4.5	18.5	3.90	4.4
5	Kakamega Kambi Somali	-	-	-	-
6	Kakamega Shirere Ponds	10.5	13.8	6.85	6
7	Kericho	5.5	34.8	-	-
8	Kiambu	3.26	25.5	3.90	4.15
9	Limuru	1.8	15.5	2.20	-
10	Thika	5.3	13	7.10	6.2
11	Kisii (Old Ponds)	-	-	7	7
12	Nanyuki	4.6	7.75	4.00	4
13	Nyahururu	8	5.38	3.20	4.3
14	Machakos (Mavuti)	4.6	12.25	4.70	4.6
15	Mavoko (Athi River)	-	-	-	-
16	Mbiri (Muranga)	4	6.88	5.00	5
17	Nairobi (Dandora)	4.5	5.25	5.00	5
18	Nairobi (Kariobangi)	1.5	6.63	4.60	4
19	Naivasha	2.18	20.5	-	-
20	Kapsabet	8.5	5.2	6.60	-
21	Nyeri (Kiganjo)	4.1	8	5.40	5.3
22	Nyeri (ADB)	4.2	10.25	4.60	4.2
23	Homa Bay	5	36.4	-	-
24	Voi	-	-	-	-
25	Kitale Conventional	3	10.4	4.00	5.5
26	Kitale Ponds	2.5	17	-	-
27	Eldoret Conventional	3	8	8.00	8
28	Eldoret Ponds	8.5	28	8.00	6
29	Isiolo (1)	-	-	-	-
30	Meru (1)	-	-	-	-
31	Nakuru Njoro (2)	-	-	-	-
32	Nakuru Town (2)	-	-	-	-
33	Kisumu (Conventional)	0.33	197	-	-
34	Kisumu Ponds - Nyalenda (3)	7.06	24	-	-
	Average	4.84	22.37	5.30	5.25
	Maximum	10.5	197	8.00	8
	Minimum	0.33	5.2	2.20	4

Source :

(1) JICA Report 1997 " The Study on the Water Supply for Seven Towns in Kenya"
(2) JICA Report 1994 " Feasibility Study on the Nakuru Sewege Works Rehabilitation and Expansion Project"
(3)JICA Report 1997 " On-going Study on Kisumu Water Supply and Sewerage System"

Table - 2.2.5 Typical Composition of Untreated Domestic Wastewater

Contaminations	Unit	Concentration		
		Weak	Medium	Strong
Solids total (TS)	mg/ℓ	350	720	1,200
Dissolved, total (TDS)	mg/ℓ	250	500	850
Fixed	mg/ℓ	145	300	525
Volatile	mg/ℓ	105	200	325
Suspended solids (SS)	mg/ℓ	100	220	350
Fixed	mg/ℓ	20	55	75
Volatile	mg/ℓ	80	165	275
Settleable solids	mg/ℓ	5	10	20
Biochemical oxygen demand, mg/l; 5-day, 20℃ (BOD_5, 20℃)	mg/ℓ	110	220	400
Total organic carbib (TOC)	mg/ℓ	80	160	290
Chemical oxygen demand (COD)	mg/ℓ	250	500	1,000
Nitrogen (total as N)	mg/ℓ	20	40	85
Organic	mg/ℓ	8	15	35
Free ammonia	mg/ℓ	12	25	50
Nitrites	mg/ℓ	0	0	0
Phosphorus (total as P)	mg/ℓ	4	8	15
Organic	mg/ℓ	1	3	5
Inorganic	mg/ℓ	3	5	10
Chlorides[a]	mg/ℓ	30	50	100
Sulfate[a]	mg/ℓ	20	30	50
Alkalinity (as $CaCO_3$)	mg/ℓ	50	100	200
Grease	mg/ℓ	50	100	150
Total coliform[b]	no/100 mℓ	10^6 - 10^7	10^7 - 10^8	10^7-10^9

Note: 1.8 (℃) + 32 = °F

a : Values should be increased by amount present in domestic water supply.

b : See Table 3-18 for typical values for other micro organisms.

Table 3.1.1 Summary of Actions Required to Overcome Constraints

Problem/constraint	Cause	Strategy	Recommended Action	Assessment of technical assistance needed
1 Inadequate investment funding	Low development priority Dependancy on donors	increase internal funding to sewerage/sanitation sector	GOK to review development plan and shift budget	not assessed
2 Insufficient information for planning	No urban land use data	- implement data collection and Information Management Systems	Feasibility study for IMS at national level	not assessed
	No M/P for urban development	establish M/P for urban centers larger than 50,000 revise M/P for urban centers every 10 years	Individual urban master planning and feasibility studies in order of priority	not assessed
3 Inadequate on-site sanitation	Incorrect construction methods Poor choice of technology Unreliable collection of septage Lack of septage disposal facilities	Regulate on-site sanitation, construction & maintenance. Provide collection equipment and disposal facilities	Feasibility study to develop standards, institutional arrangements and implementation plan for	not assessed
4 Insufficient operating revenue	Unaccounted for water	Leakage detection/correction & metering program	Technical assistance in Las to implement programs	5 PY over 3 years
	Inadequate billing & collection	Improve management process and systems		
	Sewer surcharge collected by water undertaker but not remitted to municipality Revenue for sewer operations used to fund other municipal expenses	Combine water and sewerage operations into one operating entity. Continue with commercialisation in 12 municipalities.	Supported by GTZ until 1999	3 PY over 3 years
	sewer and water tariffs do not represent operating costs	Revise tariffs to reflect true operating costs	Tariff study	4 person weeks
5 Facilities difficult to operate and maintain	No technical standards	Establish Planning & Design standards	Technical assistance in Las to implement programs	not assessed
	No operator input during design	Establish a design review process including O&M expertise		
6 Water consumption too low to support conventional sewerage	Deteriorating water supply systems	Rehabilitate and restore system capacity Leakage detection/correction & metering program	Implement infrastructure rehabilitation projects recommended by Aftercare study.	not assessed
7 Lack of qualified personnel	Inadequate staffing levels Qualifications required to fill a position are set too low	Organisational review	Technical assistance in LAs to implement programs	20 PY over 5 years
	Poor training and development of employees	National training program		
8 Inadequate tools, facilities & equipment	Insufficient operating revenue	Prepare a procurement plan for each LA Identify funds & obtain budget		
9 Inadequate maintenance management	Crisis management approach to maintenance	Implement preventive maintenance		
10 Treatment process upsets from industrial discharges	Legislation is not enforced lack of inspectors, no qualified personnel lack of equipment to sample industrial effluents	Feasibility study to devise a strategy for implementing industrial wastewater pre-treatment programs within each LA. Identify the required staffing, equipment and facilities.		
11 Poor operation of collection and treatment works	Failure of mechanical/electrical systems	Rehabilitate	Operational review of collection & treatment facilities.	not assessed
	no process monitoring or control	Develop written standard operating procedures for pumping stations and all treatment process operations.		
	organic/hydraulic overload	Rehabilitate & expand treatment capacity or provide new facilities	Implement infrastructure development projects recommended by Aftercare study.	not assessed

Table - 3.2.1 (1/2) Urban Centres with Planned Projects

	Province	District	Urban Centre	Population 95	Existing Sewerage Systems: Treatment No.	Treatment Type	Population served 95	(%)	Condition	On-Going	Idenfied in PIP & DDP
1	Nairobi	Nairobi	Nairobi	1,857,000	2	TF, SP	415,200	22.4	1. Polluting Nairobi/Athi River, 2. Conventional t/w inoperative	1. Desludging of Dandora ponds, 2.New Anaerobic ponds	
2	Coast	Mombasa	Mombasa	573,000	3	EA	69,600	12.1	1. All t/w are inoperative	New treatment works are under construction	Water supply and sewerage
3	Rift Valley	Nakuru	Nakuru	231,687	2	SP, RF,GP	123,500	53.3	1. T/w expansion JICA, 2. Improved effluent standards	management project GTZ	
4	Nyanza	Kisumu	Kisumu	231,327	2	TF, SP	130,000	56.2	1. Overloaded, 2. Sludge accumulation	1. Development study JICA, 2. management project GTZ	Expansion of water & sewerage systems
5	Eastern	Machakos	Machakos	154,006	1	SP	6,900	4.5	1. Overloaded.	new facility proposed in 85, delayed for lack of funding	master plan completed
6	Rift Valley	Uasin Gishu	Eldoret	148,204	2	TF,SP	16,907	11.4	1. Polluting Sosiani river, 2. Affected by industrial waste	1. New t/w proposed by FRG/GTZ	
7	Eastern	Meru	Meru	124,412	1	SP	800	0.6	1. Sludge accumulation, 2.overload		Municipal sewerage, relocate t/w to larger site Thuura Forest
8	Central	Nyeri	Nyeri	123,508	2	TF, SP	7,900	6.4	1. Insufficient sewage inflow to t/w	Commercialization pilot project GTZ/FDR	extend 4 sewer lines & purchase vacuum truck for septage
9	Western	Kakamega	Kakamega	77,306	2	SP	5,445	7.0	1. Sludge accumulation		De-sludging of ponds
10	Rift Valley	Trans Nzoia	Kitale	73,956	2	TF,SP	6,000	8.1	1. Low inflow	1. Management project GTZ	
11	Central	Kiambu	Thika	73,718	1	SP	11,718	15.9	1. Low inflow, 2. Sludge accumulation	1. Master plan recently completed	
12	Rift Valley	Kericho	Kericho	56,108	1	TF	4,600	8.2	1. Rehabilitated in 1997 and expanded	Commercialisation pilot project GTZ	
13	Rift Valley	Nakuru	Naivasha	51,442	1	OL, SP	2,300	4.5	1. Motor starters stolen, 2.Aerators non-operational		
14	Nyanza	Kisii	Kisii	50,604	1	SP	800	1.6	1. Sludge accumulation, 2.Overloaded	1. New system commissioned in 98	
15	Western	Bungoma	Webuye	41,935	1	SP	6,700	16.0	1. Sludge accumulation		Extend sewerage to include hospital & schools
16	Western	Bungoma	Bungoma	39,679	1	SP	900	2.3	1. not operational, low inflow	1. construction of new ponds delayed	
17	Eastern	Embu	Embu	34,309	1	SP	5,052	14.7	1. Sludge accumulation, overload		Sewerage detailed design is complete
18	Western	Busia	Busia	32,441	1	SP	2,600	8.0	1. Overloaded	complete house connections	Construct new sewage t/w
19	Rift Valley	Laikipia	Nanyuki	31,559	1	SP	10,400	33.0	1. Insufficient sewage inflow	management project GTZ	
20	Nyanza	Homa Bay	Homa Bay	30,995	1	OL, SP	2,912	9.4	1. Sludge pumps inoperative, 2. DANIDA house connection'91		Repair sewage treatment plant
21	Eastern	Isiolo	Isiolo	26,968	1	SP	1,700	6.3	1. Sludge accumulation, 2.Low inflow		house connection program
22	Central	Muranga	Muranga	26,376	1	SP	6,900	26.2	1. New t/w commissioned 1997		
23	Rift Valley	Laikipia	Nyahururu	19,446	1	OL, SP	3,239	16.7	1. Low inflow, 2. Sludge accumulation	1. management project GTZ	house connection program
24	Eastern	Machakos	Athi River	18,304	1	SP	1,310	7.2	1. New facility		land acquired for future expansion
25	Coast	Taita Taveta	Voi	15,772	1	SP	700	4.4	1. Serves housing development, 95 connections only		
26	Rift Valley	Nandi	Kapsabet + Bonaton	14,604	1	SP	4,000	27.4	1. New facility		Complete ph2, piping & pump installation
27	Rift Valley	Kajiado	Ngong	12,730	1	SP	750	5.9	1. Sludge accumulation, 2. Insufficient loading		
28	Central	Kiambu	Kiambu	8,239	1	OD	200	2.4	1. Overloaded		Rehab to double treatment capacity
29	Central	Nyeri	Karatina	7,299		SP	5,109	70	1. Overloaded, 2. J11Effluent polluting Ragati River		sewer capacity improvements
30	Central	Kiambu	Limuru	1,958	1	OD	600	30.6	1. Complete mechanical failure, 2. Effluent polluting Tigoni river		

Type of treatment: EA = extended aeration, OD=oxidation ditch, OL=oxidation lagoon, TF=trickling filter, SP=Stabilisation ponds, RF=rock filter, GP = grass plot, ST=septic tank, PL=pit latrine

Information on existing sewage t/w and served population obtained from 1995 JICA report prepared by Dr. Morita

Urban centers without sewerage that will have a population exceeding 100,000 by the year 2010 are highlighted, base population obtained from 1989 census, 1995 population estimated by JICA study team

Development status is based on a review of the Public Investment Plan for 1997 - 2000, and the District Development Plans both issued by the Ministry of Planning and National Development

Table - 3.2.1 (2/2) Urban Centres with Planned Projects

	Province	District	Urban Centre	Population 95	Existing Sewerage Systems: Treatment No.	Treatment Type	Population served 95	(%)	Condition	On-Going	Idenfied in PIP & DDP
31	Coast	Kilifi	Malindi	48,227		ST	0	0	1. Septic tanks unsatisfactory due to population density		sewerage planning complete, funding not identified
32	North Eastern	Garissa	Garissa	40,000	1	SP	0	0	1. Poor performace, 2.Effluent into Tana river		
33	Central	Muranga	Maragua	39,411		ST, PL	0	0	1. On-site systems are unsatisfactory		
34	Central	Kiambu	Ruiru	32,302	1	ST, SP	0	0	1. On-site systems are unsatisfactory		
35	North Eastern	Wajir	Wajir	26,239		ST, PL	0	0	1. High water table, on-site sanitation is unsuitable		undertake water supply & sewerage works
36	Rift Valley	Kajiado	Ongata Longai	25,080		ST, PL	0	0	1. On-site systems are unsatisfactory		
37	North Eastern	Mandera	Mandera	22,856		ST, PL	0	0	1. High water table, on-site sanitation is unsuitable		undertake water supply & sewerage works
38	Coast	Kilifi	Kilifi	20,555		ST, PL	0	0	1. Septic tanks unsatisfactory 2.Sludge disposal in Gede forest		
39	Rift Valley	Narok	Narok	19,859		ST, PL	0	0	1. On-site systems are unsatisfactory		
40	Eastern	Marsabit	Marsabit	16,084		ST, PL	0	0	1. High water table, on-site sanitation is unsuitable		Proposed water supply & sewerage study
41	Central	Kirinyaga	Kerugoya/Kutus	13,784			0	0			water supply & sewerage to minimize water pollution, GOK
42	Rift Valley	Baringo	Kabarnet	11,804		ST,PL	0	0	1. On site sanitation is unsatisfactory		Town sewerage, planning & design complete
43	Coast	Lamu	Lamu	11,437		ST, PL	0	0	1. Septic tanks & pit latrines unsatisfactory		new sewerage system to serve the whole town
44	Rift Valley	Trans Mara	Kilgoris	7,665			0	0			Construct sewage pond and piping network
45	Nyanza	Nyamira	Nyamira + Kebirigo	7,130		ST, PL	0	0	1. On site unsatisfactory, 2. Planned district HQ		Construction of sewerage system
46	Central	Nyeri	Othaya	6,379		ST, PL	0	0			sewerage study proposed
47	Eastern	Tharaka Nithi	Chuka	5,607			0	0			undertake water supply & sewerage works
48	Eastern	Mwingi	Mwingi	5,469			0	0			New Sewerage to reduce freq. outbreaks of waterborne disease
49	Western	Vihiga	Vihiga + Majengo	5,274			0	0			water supply & sewerage study
50	Rift Valley	Baringo	Marigat	4,707			0	0			Town sewerage planning
51	Western	Vihiga	Luanda	4,246			0	0			Construct a sewage t/w to allow hygenic disposal in municipality
52	Nyanza	Migori	Nyabikaye	4,184			0	0			Construction of sewerage network & t/w
53	Central	Nyandarua	Ol Kalou	3,840			0	0			Construction of new sewerage system
54	Nyanza	Nyamira	Keroka	2,640		ST, PL	0	0		Stabilization ponds designed	Construction of sewerage system
55	Nyanza	Migori	Kehancha	2,528			0	0			Construction of sewerage network & t/w
56	Eastern	Makueni	Wote	1,731			0	0			Proposed water supply & sewerage study
57	Rift Valley	Bomet	Bomet	925			0	0			undertake water supply & sewerage works
58	Western	Bungoma	Kapsakwony	795			0	0			Construct a sewerage system
59	Central	Kirinyaga	Kianyaga	498			0	0			water supply & sewerage to minimize water pollution, GOK
				4,580,148			854,742	18.7			

Type of treatment: EA = extended aeration, OD=oxidation ditch, OL=oxidation lagoon, TF=trickling filter, SP=Stabilisation ponds, RF=rock filter, GP = grass plot, ST=septic tank, PL=pit latrine
Information on existing sewage t/w and served population obtained from 1995 JICA report prepared by Dr. Morita

Development status is based on a review of the Public Investment Plan for 1997 - 2000, and the District Development Plans both issued by the Ministry of Planning and National Development

Table - 3.2.2 (1/2) Urban Centre Selected for Sewerage Development

	Province	Code	District	Code	Urban Cent43	Water & Sanitation Developement 1998					
						Urban Population [1]	Population connected to water supply [3]	Population connected to sewer [1]	Population with water but no sewerage		% of urban population connected to sewer
1	Nairobi	110	Nairobi	U-1	Nairobi	2,240,000	1,784,577	1,000,000	784,577	44%	45%
2	Central	210	Kiambu	U-4	Kiambu	7,500	8,058	2,250	5,808	72%	30%
3	Central	210	Kiambu	U-6	Limuru	3,000	1,958	2,100	0	0%	70%
4	Central	210	Kiambu	U-8	Ruiru	32,302	6,000	0	6,000	100%	0%
5	Central	210	Kiambu	U-9	Thika	155,770	120,000	87,230	32,770	27%	56%
6	Central	230	Muranga	U-20	Maragua	39,411	6,200	0	6,200	100%	0%
7	Central	230	Muranga	U-21	Muranga	30,000	24,000	10,500	13,500	56%	35%
8	Rift Valley	240	Nyandarua	U-28	Nyahururu	60,000	50,000	18,000	32,000	64%	30%
9	Central	250	Nyeri	U-33	Karatina	7,299	14,533	5,109	9,424	65%	70%
10	Central	250	Nyeri	U-36	Nyeri	142,000	40,000	37,100	2,900	7%	26%
11	Coast	310	Kilifi	U-38	Kilifi	20,555	30,170	0	30,170	100%	0%
12	Coast	310	Kilifi	U-40	Malindi	48,227[2]	141,293	0	141,293	100%	0%
13	Coast	340	Mombasa	U-52	Mombasa	580,000	370,764	69,600	301,164	81%	12%
14	Coast	350	Taita Taveta	U-55	Voi	15,772[2]	20,300	700	19,600	97%	4%
15	Eastern	410	Embu	U-60	Embu	45,000	35,000	9,000	26,000	74%	20%
16	Eastern	420	Isiolo	U-63	Isiolo	26,968	36,000	1,700	34,300	95%	6%
17	Eastern	440	Masaku	U-69	Athi River	50,000	12,500	12,500	0	0%	25%
18	Eastern	440	Masaku	U-71	Machakos	154,006	80,000	8,000	72,000	90%	5%
19	Eastern	460	Meru	U-86	Meru	124,412[2]	16,330	800	15,530	95%	1%
20	North Eastern	510	Garissa	U-104	Garissa	40,000[2]	34,758	0	34,758	100%	0%

estimated by JICA study team.

Note (3) - from various sources gathered by JICA study team.

Table - 3.2.2 (2/2) Urban Centre Selected for Sewerage Development

	Province	Code	District	Code	Urban Centre	Water & Sanitation Development 1998: Urban Population	Population connected to water supply	Population connected to sewer	Population with water but no sewerage		% of urban population connected to sewer
21	North Eastern	520	Mandera	U-109	Mandera	22,856	8,160	0	8,160	100%	0%
22	North Eastern	530	Wajir	U-116	Wajir	26,239	1,500	0	1,500	100%	0%
23	Nyanza	610	Kisii	U-117	Kisii	65,000	45,000	13,000	32,000	71%	20%
24	Nyanza	620	Kisumu	U-120	Kisumu	231,327(2)	280,845	130,000	150,845	54%	56%
25	Nyanza	640	Homa Bay	U-129	Homa Bay	75,000	43,000	15,000	28,000	65%	20%
26	Rift Valley	710	Kajiado	U-144	Ngong	15,000	6,000	750	5,250	88%	5%
27	Rift Valley	710	Kajiado	U-146	Ongata Longai	25,080	7,200	0	7,200	100%	0%
28	Rift Valley	720	Kipsigis	U-148	Kericho	80,000	58,723	41,600	17,123	29%	52%
29	Rift Valley	730	Laikipia	U-153	Nanyuki	55,000	43,100	24,750	18,350	43%	45%
30	Rift Valley	740	Nakuru	U-158	Naivasha	60,000	46,000	30,000	16,000	35%	50%
31	Rift Valley	740	Nakuru	U-159	Nakuru	231,687	304,561	123,500	181,061	59%	53%
32	Rift Valley	750	Narok	U-163	Narok	19,859	12,000	0	12,000	100%	0%
33	Rift Valley	760	Trans Nzoia	U-164	Kitale	75,000	60,000	37,500	22,500	38%	50%
34	Rift Valley	770	Uasin Gishu	U-166	Eldoret	220,000	90,000	70,400	19,600	22%	32%
35	Rift Valley	810	Baringo	U-179	Kabarnet	11,804	127,500	0	127,500	100%	0%
36	Rift Valley	830	Nandi	U-185	Kapsabet + Baraton	20,000	7,000	4,000	3,000	43%	20%
37	Western	910	Bungoma	U-199	Bungoma	70,000	36,000	12,600	23,400	65%	18%
38	Western	910	Bungoma	U-205	Webuye	60,000	40,000	12,000	28,000	70%	20%
39	Western	920	Busia	U-206	Busia	48,000	17,267	9,600	7,667	44%	20%
40	Western	930	Kakamega	U-210	Kakamega	77,306(2)	27,826	5,445	22,381	80%	7%

	1998			
			Urban population connected to sewers	
Population living in urban centers where sewerage is available	4,017,986		1,794,734	45%
Total population in all urban centers.	6,576,000		1,794,734	28%

Notes: (1) - Populations reported by municipal and town councils during JICA study team survey, (2) - Information not reported in survey or incorrect therefore population shown is for 1995 as
Note (3) - from various sources gathered by JICA study team.

Table - 3.3.1 Descriptive Comparison of Sanitation Technologies

Sanitation technology	Rural application	Urban application	Construction cost	Operating cost	Ease of construction	Self-help potential	Water requirement	Required soil conditions	Complementary off-site investment [a]	Reuse potential	Health benefits	Institutional requirements
Ventilated improved pit (VIP) latrines and Reed Odorless Earth Closets (ROECS)	Suitable	Suitable in L/M-density areas	L	L	Very easy except in wet or rocky ground	H	None	Stable permeable soil; groundwater at least 1 meter below surface b	None	L	Good	L
Pour-flush (PF) toilets	Suitable	Suitable in L/M-density areas	L	L	Easy	H	Water near toilet	Stable permeable soil; groundwater at least 1 meter below surface b	None	L	Very good	L
Double vault composing (DVC) toilets	Suitable	Suitable in L/M-density areas	M	L	Very easy except in wet or rocky ground	H	None	None (can be built above ground)	None	H	Good	L
Self-topping aquaprivy	Suitable	Suitable in L/M-density areas	M	L	Requires some skilled labor	H	Water near toilet	Stable permeable soil; groundwater at least 1 meter below surface b	Treatment facilities for sludge	M	Very good	L
Septic tank	Suitable for rural institutions	Suitable in L/M-density areas	H	H	Requires some skilled labor	L	Water piped to house and toilet	Stable permeable soil; groundwater at least 1 meter below surface b	Off-site treatment facilities for sludge	M	Very good	L
Three-stage septic tanks	Suitable	Suitable in L/M-density areas	M	L	Requires some skilled labor	H	Water near toilet	Stable permeable soil; groundwater at least 1 meter below surface b	Treatment facilities for sludge	M	Very good	L
Vault toilets and cartage	Not suitable	Suitable	M	H	Requires some skilled labor	H (for vault construction)	Water near toilet	None (can be built above ground)	Treatment facilities for sludge	H	Very good	VH
Seaward PI toilets, septic tanks, aquaprivies	Not suitable	Suitable	H	M	Requires skilled engineer/builder	L	Water piped to house and toilet	None	Sewers and treatment facilities	H	Very good	H
Sewerage	Not suitable	Suitable	VH	H	Requires skilled engineer/builder	L	Water piped to house and toilet	None	Sewers and treatment facilities	H	Very good	H
Shallow sewerage	Not suitable	Suitable	L	L	Requires skilled engineer/builder	M	Water near toilet	None	Sewers and treatment facilities	H	Very good	M

Source: J.M. Kalbermatten, and ohters, Appropriate Sanitation Alternatives: A Planning and Design Manual (Baltimore, Johns Hopkins University Press, 1982, p.160 (modified to include shallow sewerage).

Notes: L = Low, M = medium, H = High, VH = Very High

a. On- or of-site sullage disposal facilities are required for nonsewered technologies with water service levels in excess of 50 to 100 lcd, depending on population density.

b. If groundwater is less than 1 meter below the surface, a plinth can be built.

Table - 3.4.1(1/2) Sewerage Development Targets

	Province		District		Urban Center	Water & Sanitation Developement in 1998						Water & Sanitation Developement in 2010				Incremental population requiring sewerage by 2010
						Urban Population [1]	Population connected to water supply [3]	Population connected to sewer [1]	Population with water but no sewerage		% of urban population connected to sewer	Urban Population	Population connected to water supply	Population connected to sewer	% of urban population connected to sewer	
1	Nairobi	110	Nairobi	U-1	Nairobi	2,240,000	1,784,577	1,000,000	784,577	44%	45%	3,023,000	2,932,310	1,511,500	50	511,500
2	Central	210	Kiambu	U-4	Kiambu	7,500	8,058	2,250	5,808	72%	30%	21,356	14,241	6,407	30	4,157
3	Central	210	Kiambu	U-6	Limuru	3,000	1,958	2,100	0	0%	70%	4,347	4,129	3,043	70	943
4	Central	210	Kiambu	U-8	Ruiru	32,302	6,000	0	6,000	100%	0%	70,142	106,041	17,500	25	17,500
5	Central	210	Kiambu	U-9	Thika	155,770	120,000	87,230	32,770	27%	56%	190,350	212,082	95,175	50	7,945
6	Central	230	Muranga	U-20	Maragua	39,411	6,200	0	6,200	100%	0%	79,924	27,266	20,021	25	20,021
7	Central	230	Muranga	U-21	Muranga	30,000	24,000	10,500	13,500	56%	35%	62,635	105,547	21,980	35	11,480
8	Rift Valley	240	Nyandarua	U-28	Nyahururu	60,000	50,000	18,000	32,000	64%	30%	60,186	150,583	18,056	30	56
9	Central	250	Nyeri	U-33	Karatina	7,299	14,533	5,109	9,424	65%	70%	19,471	38,767	13,630	70	8,521
10	Central	250	Nyeri	U-36	Nyeri	142,000	40,000	37,100	2,900	7%	26%	331,393	217,108	165,697	50	128,597
11	Coast	310	Kilifi	U-38	Kilifi	20,555	30,170	0	30,170	100%	0%	57,082	41,335	14,300	25	14,300
12	Coast	310	Kilifi	U-40	Malindi	48,227[2]	141,293	0	141,293	100%	0%	134,152	193,580	53,661	40	53,661
13	Coast	340	Mombasa	U-52	Mombasa	580,000	370,764	69,600	301,164	81%	12%	736,000	476,234	368,000	50	298,400
14	Coast	350	Taita Taveta	U-55	Voi	15,772[2]	20,300	700	19,600	97%	4%	35,159	46,991	8,800	25	8,100
15	Eastern	410	Embu	U-60	Embu	45,000	35,000	9,000	26,000	74%	20%	92,214	93,054	23,100	25	14,100
16	Eastern	420	Isiolo	U-63	Isiolo	26,968	36,000	1,700	34,300	95%	6%	83,440	78,896	20,902	25	19,202
17	Eastern	440	Masaku	U-69	Athi River	18,300	12,500	1,300	11,200	90%	7%	48,441	42,911	12,110	25	10,810
18	Eastern	440	Masaku	U-71	Machakos	154,006	80,000	8,000	72,000	90%	5%	407,822	274,630	203,911	50	195,911
19	Eastern	460	Meru	U-86	Meru	124,412[2]	16,330	800	15,530	95%	1%	337,437	218,467	168,718	50	167,918
20	North Eastern	510	Garissa	U-104	Garissa	40,000[2]	34,758	0	34,758	100%	0%	115,126	82,850	46,051	40	46,051

Table - 3.4.1(2/2) Sewerage Development Targets

	Province		District		Urban Center	Water & Sanitation Developement in 1998						Water & Sanitation Developement in 2010				Incremental population requiring sewerage by 2010
						Urban Population (1)	Population connected to water supply (3)	Population connected to sewer (1)	Population with water but no sewerage		% of urban population connected to sewer	Urban Population	Population connected to water supply	Population connected to sewer	% of urban population connected to sewer	
21	North Eastern	520	Mandera	U-109	Mandera	22,856	8,160	0	8,160	100%	0%	51,680	29,603	12,900	25	12,900
22	North Eastern	530	Wajir	U-116	Wajir	26,239	1,500	0	1,500	100%	0%	66,062	61,637	16,500	25	16,500
23	Nyanza	610	Kisii	U-117	Kisii	65,000	45,000	13,000	32,000	71%	20%	120,615	114,584	48,246	40	35,246
24	Nyanza	620	Kisumu	U-120	Kisumu	231,327(2)	280,845	130,000	150,845	54%	56%	561,029	441,418	280,514	50	150,514
25	Nyanza	640	Homa Bay	U-129	Homa Bay	75,000	43,000	15,000	28,000	65%	20%	71,860	90,372	18,000	25	3,000
26	Rift Valley	710	Kajiado	U-144	Ngong	15,000	6,000	750	5,250	88%	5%	41,207	24,471	10,300	25	9,550
27	Rift Valley	710	Kajiado	U-146	Ongata Longai	25,080	7,200	0	7,200	100%	0%	81,185	29,365	20,337	25	20,337
28	Rift Valley	720	Kipsigis	U-148	Kericho	80,000	58,723	41,600	17,123	29%	52%	152,522	148,636	76,261	50	34,661
29	Rift Valley	730	Laikipia	U-153	Nanyuki	55,000	43,100	24,750	18,350	43%	45%	97,975	131,804	44,089	45	19,339
30	Rift Valley	740	Nakuru	U-158	Naivasha	60,000	46,000	30,000	16,000	35%	50%	168,905	110,824	84,452	50	54,452
31	Rift Valley	740	Nakuru	U-159	Nakuru	231,687	304,561	123,500	181,061	59%	53%	760,237	733,756	380,119	50	256,619
32	Rift Valley	750	Narok	U-163	Narok	19,859	12,000	0	12,000	100%	0%	77,231	73,369	19,347	25	19,347
33	Rift Valley	760	Trans Nzoia	U-164	Kitale	75,000	60,000	37,500	22,500	38%	50%	229,328	217,862	114,664	50	77,164
34	Rift Valley	770	Uasin Gishu	U-166	Eldoret	220,000	90,000	70,400	19,600	22%	32%	450,629	354,259	225,314	50	154,914
35	Rift Valley	810	Baringo	U-179	Kabarnet	11,804	127,500	0	127,500	100%	0%	32,363	189,666	8,100	25	8,100
36	Rift Valley	830	Nandi	U-185	Kapsabet + Bamton	20,000	7,000	4,000	3,000	43%	20%	44,693	42,458	11,200	25	7,200
37	Western	910	Bungoma	U-199	Bungoma	70,000	36,000	12,600	23,400	65%	18%	114,086	99,395	45,634	40	33,034
38	Western	910	Bungoma	U-205	Webuye	60,000	40,000	12,000	28,000	70%	20%	120,647	110,439	48,259	40	36,259
39	Western	920	Busia	U-206	Busia	48,000	17,267	9,600	7,667	44%	20%	103,635	98,433	41,454	40	31,854
40	Western	930	Kakamega	U-210	Kakamega	77,306(2)	27,826	5,445	22,381	80%	7%	202,516	160,123	81,006	40	75,561

	1998						2010			
Urban population connected to sewers			1,783,534						4,379,257	
Population living in urban centers where sewerage is available	3,986,286		45%				9,458,078		46%	
Total population in all urban centers.	6,576,000		27%				11,500,000		38%	

Note: (1) - Populations reported by municipal and town councils during JICA study team survey.
(2) - Information not reported in survey or incorrect therefore population shown is for 1995 as estimated by JICA study team.
(3) - from various sources gathered by the Aftercare Study Team

Table - 3.4.2 Anticipated Service Levels by Sanitation Method - 2010

Urban Centre Characteristics			Urban Population 2010		Sewerage		On-Site	
Population	Number of cities	% Distribution	000's	%	000's	%	000's	%
P>300,000	8	4	6,608	57	1,687	26	4,921	74
300,000>P>100,000	11	5	1,652	14	1,053	64	599	36
100,000>P>20,000	54	25	2,349	20	1,510	64	838	36
P<20,000	142	66	892	8	122	14	769	86
Total	215		11,501		4,373	38	7,128	62

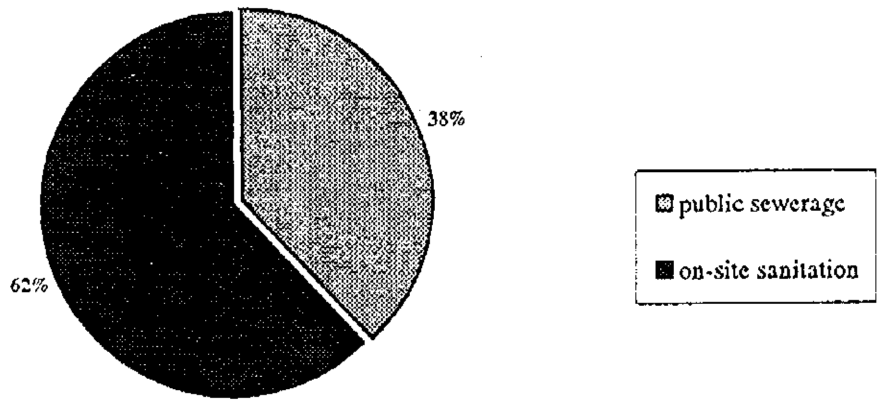


Table - 3.5.1 (1/2) Wastewater Flow Calculation in 2010

	Code	Urban Centre	Sewerage Developement 1998						Sewerage Developement 2010			Waste water flow 2010							
						Present Sewage Flow						A	B	C	D=A+B+C	E	Dry weather flow F=D+E		Incremental treatment capacity m3/day
			Urban Population 1998	Population connected to sewer	% of urban population connected to sewers	Treatment Works Capacity m3/day	m3/day	Liters per Capita/day	Urban Population	Population connected to sewer	% of urban population served by sewers	Domestic sewage discharge m3/day	Commercial/ institutional/ Public m3/day	Industrial sewage discharge m3/day	Total sewage flow m3/day	Infiltration/Inflow allowance m3/day	Total m3/day	Per Capita m3/day	
1	U-1	Nairobi	2,240,000	1,000,000	45%	112,000	217,000	217	3,023,000	1,511,500	50	140,570	46,857	46,857	234,283	46,857	281,139	186	169,139
2	U-159	Nakuru	231,687	123,500	53%	16,200	8,181	66	760,237	380,119	50	35,351	11,784	11,784	58,918	11,784	70,702	186	54,502
3	U-52	Mombasa	580,000	69,600	12%	49,600	4,590	66	736,000	368,000	50	34,224	11,408	11,408	57,040	11,408	68,448	186	18,848
4	U-120	Kisumu	231,327	130,000	56%	17,800	15,000	115	561,029	280,514	50	26,088	8,696	8,696	43,480	8,696	52,176	186	34,376
5	U-166	Eldoret	220,000	70,400	32%	6,375	NFM		450,629	225,314	50	20,954	6,985	6,985	34,924	6,985	41,908	186	35,533
6	U-71	Machakos	80,000	8,000	10%	2,000	3,000	375	407,822	203,911	50	18,964	6,321	6,321	31,606	6,321	37,927	186	35,927
7	U-86	Meru	124,412	800	1%	2,500	500	625	337,437	168,718	50	15,691	5,230	5,230	26,151	5,230	31,382	186	28,882
8	U-36	Nyeri	142,000	37,100	26%	8,100	2,500	67	331,393	165,697	50	15,410	5,137	5,137	25,683	5,137	30,820	186	22,720
9	U-164	Kitale	75,000	37,500	50%	2,930	NFM		229,328	114,664	50	10,664	3,555	3,555	17,773	3,555	21,327	186	18,397
10	U-210	Kakamega	110,000	51,700	47%	5,500	4,800	93	202,516	101,258	50	9,417	3,139	3,139	15,695	3,139	18,834	186	13,334
11	U-9	Thika	155,770	87,230	56%	6,100	10,000	115	190,350	95,175	50	8,851	2,950	2,950	14,752	2,950	17,703	186	11,603
12	U-158	Naivasha	60,000	30,000	50%	2,035	700	23	168,905	84,452	50	7,854	2,618	2,618	13,090	2,618	15,708	186	13,673
13	U-148	Kericho	80,000	41,600	52%	1,500	2,000	48	152,522	76,261	50	7,092	2,364	2,364	11,820	2,364	14,185	186	12,685
14	U-40	Malindi	48,227	0	0%	0	0	0	134,152	53,661	40	4,990	1,663	1,663	8,317	1,663	9,981	186	9,981
15	U-205	Webuye	60,000	12,000	20%	NA	1,500	125	120,647	48,259	40	4,488	1,496	1,496	7,480	1,496	8,976	186	8,976
16	U-117	Kisii	65,000	13,000	20%	NA	NFM		120,615	48,246	40	4,487	1,496	1,496	7,478	1,496	8,974	186	8,974
17	U-104	Garissa	40,000	0	0%	0	0	0	115,126	46,051	40	4,283	1,428	1,428	7,138	1,428	8,565	186	8,565
18	U-199	Bungoma	70,000	12,600	18%	45	NFM		114,086	45,634	40	4,244	1,415	1,415	7,073	1,415	8,488	186	8,443
19	U-206	Busia	48,000	9,600	20%	600	600	63	103,635	41,454	40	3,855	1,285	1,285	6,425	1,285	7,710	186	7,110
20	U-153	Nanyuki	55,000	24,750	45%	2,270	8,000	323	97,975	44,089	45	4,100	1,367	1,367	6,834	1,367	8,200	186	5,930

Table - 3.5.1 (2/2) Wastewater Flow Calculation in 2010

	Code	Urban Center	Sewerage Developement 1998						Sewerage Development 2010			Waste water flow 2010							
			Urban Population 1998	Population connected to sewer	% of urban population connected to sewers	Present Sewage Flow			Urban Population	Population connected to sewer	% of urban population served by sewers	A	B	C	D=A+B+C	E	Dry weather flow F=D+E		Incremental treatment capacity m3/day
						Treatment Works Capacity m3/day	m3/day	Liters per Capita/day				Domestic sewage discharge m3/day	Commercial/ institutional/ Public m3/day	Industrial sewage discharge m3/day	Total sewage flow m3/day	Infiltration/Inflow allowance m3/day	Total m3/day	Per Capita m3/day	
21	U-60	Embu	45,000	9,000	20%	682	180	20	92,214	23,018	25	2,141	714	714	3,568	714	4,281	186	3,590
22	U-63	Isiolo	26,968	1,700	6%	2,000	600	353	83,440	20,340	25	1,938	646	646	3,230	646	3,876	186	1,876
23	U-146	Ongata Longai	25,080	0	0%	0	0	0	81,185	20,296	25	1,888	629	629	3,146	629	3,775	186	3,775
24	U-20	Maragua	39,411	0	0%	0	0	0	79,924	19,981	25	1,858	619	619	3,097	619	3,716	186	3,716
25	U-163	Narok	19,859	0	0%	0	0	0	77,231	19,345	25	1,799	600	600	2,999	600	3,598	186	3,598
26	U-129	Homa Bay	75,000	15,000	20%	750	1,045	70	71,860	17,962	25	1,670	557	557	2,784	557	3,341	186	2,591
27	U-8	Ruiru	32,302	0	0%	0	0	0	70,142	17,571	25	1,634	545	545	2,724	545	3,268	186	3,268
28	U-116	Wajir	26,239	0	0%	0	0	0	66,062	16,516	25	1,536	512	512	2,560	512	3,072	186	3,072
29	U-21	Muranga	30,000	10,500	35%	1,564	870	83	62,635	21,922	35	2,039	680	680	3,398	680	4,078	186	2,514
30	U-28	Nyahururu	60,000	18,000	30%	2,500	3,436	191	60,186	30,093	50	2,799	933	933	4,664	933	5,597	186	3,097
31	U-38	Kilifi	20,555	0	0%	0	0	0	57,082	14,271	25	1,327	442	442	2,212	442	2,654	186	2,654
32	U-109	Mandera	22,856	0	0%	0	0	0	51,680	12,946	25	1,204	401	401	2,007	401	2,408	186	2,408
33	U-69	Athi River	18,000	1,300	7%	12,960	1,000	769	48,441	12,110	25	1,126	375	375	1,877	375	2,252	186	0
34	U-185	Kapsabet + Baraton	20,000	4,000	20%	1,000	NFM		44,693	11,173	25	1,039	346	346	1,732	346	2,078	186	1,078
35	U-144	Ngong	15,000	750	5%	230	15	20	41,207	10,314	25	959	320	320	1,599	320	1,918	186	1,688
36	U-55	Voi	15,772	700	4%	0	0	0	35,159	8,811	25	819	273	273	1,366	273	1,639	186	1,639
37	U-179	Kabarnet	11,804	0	0%	0	0	0	32,363	8,091	25	752	251	251	1,254	251	1,505	186	1,505
38	U-4	Kiambu	7,500	2,250	30%	960	300	133	21,356	6,407	30	596	199	199	993	199	1,192	186	232
39	U-33	Karatina	7,299	5,109	70%	317	561	110	19,471	13,630	70	1,268	423	423	2,113	423	2,535	186	2,218
40	U-6	Limuru	3,000	2,100	70%	550	113	56	4,347	3,043	70	283	94	94	472	94	566	186	16
									Population connected to sewers	4,411,315		Per capita contributions							
												93	31	31	155	31	186		

Note : average domestic sewage flow (liters per capita) 93
domestic sewage as a percent of total sewage 60%
sewage from commercial, institutional and public areas as a percent of total sewage 20%
industrial wastewater as % of total sewage 20%
infiltration and surface water inflow allowance 20%

Table - 3.5.2 Septage Generated from On-site Sanitation in 2010

1	Province	Code	District	Code	Urban Centre	Population 2010			
						Total Population	with sewer connection	with septic tanks	Total septage m³/year
1	Nairobi	110	Nairobi	U-1	Nairobi	3,023,000	1,511,500	377,875	107,065
2	Central	210	Kiambu	U-4	Kiambu	21,356	6,407	3,737	1,059
3	Central	210	Kiambu	U-6	Limuru	4,347	3,043	326	92
4	Central	210	Kiambu	U-8	Ruiru	70,142	17,500	13,161	3,729
5	Central	210	Kiambu	U-9	Thika	190,350	95,175	23,794	6,742
6	Central	230	Muranga	U-20	Maragua	79,924	20,021	14,976	4,243
7	Central	230	Muranga	U-21	Muranga	62,635	21,922	10,178	3,325
8	Rift Valley	240	Nyandarua	U-28	Nyahururu	60,186	30,093	7,523	2,984
9	Central	250	Nyeri	U-33	Karatina	19,471	13,630	1,460	414
10	Central	250	Nyeri	U-36	Nyeri	331,393	165,697	41,424	11,737
11	Coast	310	Kilifi	U-38	Kilifi	57,082	14,300	10,696	3,030
12	Coast	310	Kilifi	U-40	Malindi	134,152	53,661	20,123	5,701
13	Coast	340	Mombasa	U-52	Mombasa	736,000	368,000	92,000	26,067
14	Coast	350	Taita Taveta	U-55	Voi	35,159	8,800	6,590	1,867
15	Eastern	410	Embu	U-60	Embu	92,214	23,100	17,278	4,896
16	Eastern	420	Isiolo	U-63	Isiolo	83,440	20,902	15,634	4,430
17	Eastern	440	Masaku	U-69	Athi River	48,441	12,110	9,083	2,573
18	Eastern	440	Masaku	U-71	Machakos	407,822	203,911	50,978	14,444
19	Eastern	460	Meru	U-86	Meru	337,437	168,718	42,180	11,951
20	North Eastern	510	Garissa	U-104	Garissa	115,126	46,051	17,269	4,893
21	North Eastern	520	Mandera	U-109	Mandera	51,680	12,900	9,695	2,747
22	North Eastern	530	Wajir	U-116	Wajir	66,062	16,500	12,391	3,511
23	Nyanza	610	Kisii	U-117	Kisii	120,615	48,246	18,092	5,126
24	Nyanza	620	Kisumu	U-120	Kisumu	561,029	280,514	70,129	19,870
25	Nyanza	640	Homa Bay	U-129	Homa Bay	71,860	18,000	13,465	3,815
26	Rift Valley	710	Kajiado	U-144	Ngong	41,207	10,300	7,727	2,189
27	Rift Valley	710	Kajiado	U-146	Ongata Longai	81,185	20,337	15,212	4,310
28	Rift Valley	720	Kipsigis	U-148	Kericho	152,522	76,261	19,065	5,402
29	Rift Valley	730	Laikipia	U-153	Nanyuki	97,975	44,089	13,472	3,817
30	Rift Valley	740	Nakuru	U-158	Naivasha	168,905	84,452	21,113	5,982
31	Rift Valley	740	Nakuru	U-159	Nakuru	760,237	380,119	95,030	26,925
32	Rift Valley	750	Narok	U-163	Narok	77,231	19,347	14,471	4,100
33	Rift Valley	760	Trans Nzoia	U-164	Kitale	229,328	114,664	28,666	8,122
34	Rift Valley	770	Uasin Gishu	U-166	Eldoret	450,629	225,314	56,329	15,960
35	Rift Valley	810	Baringo	U-179	Kabarnet	32,363	8,100	6,066	1,719
36	Rift Valley	830	Nandi	U-185	Kapsabet + Baraton	44,693	11,200	8,373	2,372
37	Western	910	Bungoma	U-199	Bungoma	114,086	45,634	17,113	4,849
38	Western	910	Bungoma	U-205	Webuye	120,647	48,259	18,097	5,128
39	Western	920	Busia	U-206	Busia	103,635	41,454	15,545	4,405
40	Western	930	Kakamega	U-210	Kakamega	202,516	101,258	25,314	8,607