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OFFICE OF ENERGY, ENVIRONMENT,
AND TECHNOLOGY
USAID/SRI LANKA

PRE-FEASIBILITY STUDY FOR WASTEWATER MANAGEMENT

SRI JAYAWARDENEPURA KOTTE

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Prepared for:
Urban Development Authority

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SUMMARY

INTRODUCTION

Sri Jayawardenepura Kotte covers 4227 hectares which includes the administrative areas of three Local Authorities – Kotte Urban Council, Battaramulla Unit of Kaduwela Pradeshiya Sabha, and the northern area of the Maharagama Pradeshiya Sabha. The estimated population of the city area is currently 244,000.

The Development Plan of Kotte is currently being revised by the Urban Development Authority (UDA). This plan will take into consideration the current development trend and future needs of the city. One of the main constraints for large scale developments is the provision of sewerage infrastructure facilities.

In April of 1996, USAID initiated a project through the Center for Environment's Office of Energy, Environment and Technology to assist the UDA in assessing the existing conditions at Kotte in order to outline a planning strategy for properly managing the wastewater and excreta disposal. The project personnel from this initiative have identified the immediate need for a site-specific survey of the study area in order to properly assess the existing conditions and develop the appropriate strategy. There is sufficient information for the Kotte Urban Council area to allow for assessing the existing situation. There is very little information, however, for the newer urban expansion areas of the Battaramulla Unit and the Maharagama sector that is within the boundaries of Kotte.

OBJECTIVE AND SCOPE OF SERVICES

The main objective of this effort is to undertake a pre-feasibility study and propose short-term and long-term strategies for the provision of sewerage infrastructure facilities for Sri Jayawardenepura Kotte in order to accommodate the future demand and facilitate the implementation of the UDA's Development Plan.

This effort included the following:

- Study the existing land use and population distribution pattern as well as the UDA's development Plan for the study area in order to determine the sewerage requirements.
- Review the previous proposals and plans prepared for sewerage disposal scheme for the Kotte area.
- Identify short-term and long-term options available for safe disposal of sewerage in Kotte.
- Prepare a conceptual design proposal and preliminary estimates for an economically viable, technically feasible and environmentally acceptable sewerage disposal system

and also identify priority areas for implementation according to the present and future sewerage requirements.

The proposed strategy should be formulated while taking into consideration the on-going and proposed activities in respect to sewerage infrastructure improvements in the city of Colombo.

EXISTING CONDITIONS

With the exception of the Parliament and a local hospital, the entire area does not have sewerage infrastructure facilities. The current methods of wastewater and excreta disposal include a variety of on-site systems, such as: latrines, soakage pits, septic tanks, etc. The hydrogeologic conditions of many sectors of the study area may not be suitable for such on-site disposal systems, creating a concern for significant adverse effects on public health and environmental conditions in the area. Moreover, as many businesses and government agencies continue to migrate to this new growth area, the potential for adverse public health and environmental conditions increases.

In general, existing on-site systems have a poor design and lack a soil adsorption system. There are no local or national ordinances or codes specifying the proper design of onsite sanitation systems. Some homeowners discharge only the toilet water to the septic tank and the gray waters are discharged to the ground surface. In some instances, the septic tank outlet discharges to the ground surface or to a nearby body of water.

The estimated current wastewater volume generated in the study area ranges from 23,656 to 27,394 m^3/day. This means that currently about 8.6 to 10.0 million cubic meters of sewage per year are discharged to the subsurface and, in some instances, directly into the surface bodies of water. It is possible that a large quantity of the wastewater ends up in the nearby canals and marshlands via runoff or seepage through the soil.

The current situation regarding inadequate sanitation practices poses a serious threat to the public health and the environment. This threat is anticipated to increase as the population density increases in this area. The following waterborne diseases have been reported in the study area:

- Viral Hepatitis
- Intestinal infections- diarrheal diseases
- Dengue fever
- Japanese Encephalitis
- Leptospirosis
- Malaria
- Cholera

FUTURE CONDITIONS

The future wastewater generation and water consumption estimates for the Kotte U.C. area are summarized in this table.

Year	*Wastewater* m^3/day	*Water* m^3/day
1996	24,390	22,956
2000	26,401	24,848
2010	32,183	30,290
2020	39,230	36,923

The wastewater volume is estimated higher based on the potential for infiltration into the sewer lines. The estimates are based on an annual growth rate of 2 percent .

Current sanitation practices have been carried on without ordinances or codes that require specific design for onsite disposal systems. Consequently, most of the builders have put in place inadequate or sub-standard systems. Moreover, as future population density increases, this situation poses a serious threat to the public health and the environment.

ASSESSMENT OF WASTEWATER AND EXCRETA MANAGEMENT OPTIONS

Several technologies may provide adequate wastewater treatment and disposal for the current and projected population of the study area. These technologies were evaluated and screened based on cost, environmental consequences, effectiveness, reliability, flexibility, implementability, and regional and islandwide compatibility of the project alternative plans.

The technologies considered fall into one of the following groups:

- On-site treatment and disposal
- Collection and transport for centralized treatment
- Centralized treatment and disposal
- Wastewater flow reduction

On-site Treatment and Disposal

The use of a septic tank and leaching field is the preferred on-site technology for new construction in low density areas where collection systems and centralized treatment are not available or feasible in the short-term. Other technologies presented in Section 4 can be considered when the terrain's physical conditions are inadequate for a septic tank and leaching field system. A community system may be suitable for a cluster of single family homes or multi-story buildings, office complexes, commercial areas, etc. This type of

6

application includes: a collection system, a septic tank and a leaching field, or a package treatment plant with surface discharge.

The average estimated cost for installing a septic tank/leaching field system in a single-family home is about $950 USD or Rs52,250. The average cost for a similar system serving a group of homes with about 200 people is estimated at $ 13,500 USD or Rs742,500.

Areawide (Centralized) System

The areawide systems require a sewer collection system and a treatment and/or disposal system. The technologies to be considered for further evaluation include:

Alternative 1 - Trickling Filters
Alternative 2 - Trickling Filters coupled with Wetlands
Alternative 3 - Conventional Activated Sludge
Alternative 4 - Extended Aeration Process
Alternative 5 - Facultative Lagoons
Alternative 6 - Primary Treatment and Pumping

Wastewater Flow Reduction

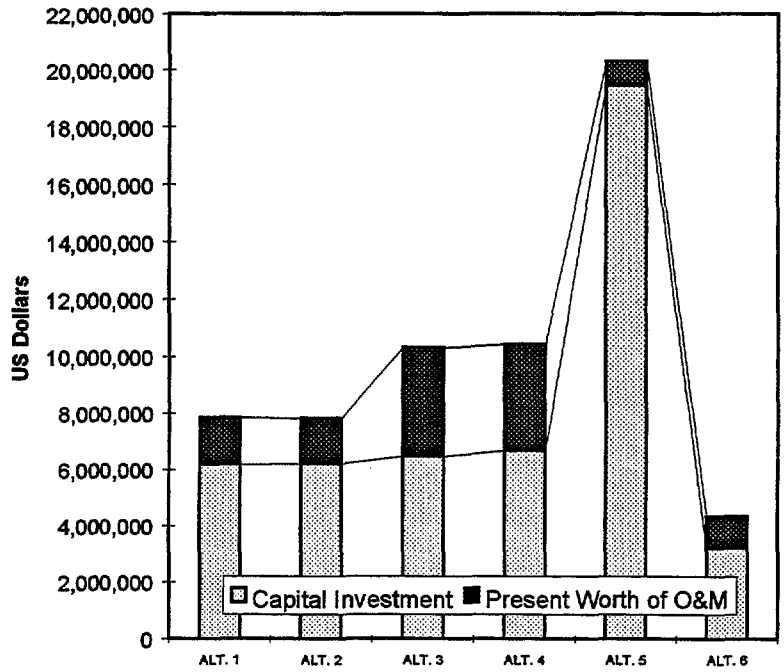
The wastewater flow reduction practice is part of integrated water and wastewater management programs and involves:

- Public information and awareness campaign;
- Implementation of micro- and macro-monitoring of the water supply system;
- General reduction of unaccounted-for-water;
- Implementation of measures such as pressure regulation; and
- Use of wastewater flow reduction methods such as: elimination of water leaks, maintaining adequate water pressure, restrictions on faucet flow in high pressure areas, and wastewater recycle and reuse.

CONCLUSIONS AND RECOMMENDATION

The figure below shows the present worth cost analysis summary for the treatment and/or disposal alternatives. All these alternatives require a collection system which is common to all the six alternatives analyzed. The cost of the collection system is not included in the figure. For comparison of alternatives, the analysis assumes a 20 year period at 10 percent interest with no salvage value.

Summary of Present Worth Analysis of Wastewater Treatment Alternatives, for the Kotte U.C. to the Year 2000



Based on this cost-effectiveness analysis, the preferred alternative is Alternative 6 – preliminary treatment and disposal via the Wellawatta Southern Outfall. This alternative includes preliminary treatment (screening and grit removal) and pumping from southwest Kotte UC to the junction box of the Southern Outfall via a 4 kilometer long, 900 mm diameter ductile iron pipe. The second best option is Alternative 2 - the trickling filter system with wetland disposal. The cost of the collection system adds about 8.12 million USD or MRs 487.2 to the cost of the treatment plant system.

Capital Investment

The capital investment is as follows:

Sewer Collection System	=	8.12 million USD or MRs 487.2
Outfall Disposal	=	3.20 million USD or MRs 192.0
Total	=	11.32 million USD or MRs 679.2

Operation and Maintenance Requirements

The proposed system includes the sewer collection system, preliminary treatment and ocean disposal. The sewer system O&M would require a staff of about 30 people to handle the sewers, force mains and lift stations in Kotte UC. The staff would be based at the Kotte U.C. public works. The pumping station would require a workforce of about 12 employees including: one general manager, two operators, six laborers, one mechanic, one electrician, and one laboratory technician. An administration building will be necessary to house the staff. In addition, the O&M staff would require vehicles, basic utilities (water, telephone, electricity, etc.), spare parts, and supplies.

Operation and Maintenance Costs

The expected first-year annual O&M cost of the proposed system is about $0.54 million USD or MRs 16.2.

Possible Tariff Scenarios for Cost Recovery

The average annual debt service on the amortized capital of $11.32 million USD or MRs 679.2, is about $1.3 million USD or MRs 68.75 (at 10 percent interest for 20 years without salvage value). Therefore, the total minimum annual revenues to make this project pay back the debt is about $1.85 million USD or MRs 110.6 (assuming that the first year O&M cost is constant through the life of the project).

User Charge Scenario. An average annual sewer tariff would be about $61.70 USD or Rs 3,702 per customer (assuming 30,000 customers). This would be invoiced with the water bill. The unit cost is estimated at about $0.211 USD or about Rs 12.67 per m^3 (based on 24,000 m^3 per day).

Property Tax. If the tariff is charged to the property taxes, and assuming there are about 1,500 ha. of private property in Kotte U.C., the average additional taxes of property would be about $0.123 USD/ m^2 or about Rs 7.4 per m^2 per year (or about Rs 187 per Perch). This represents less than 0.21 percent of the average value of land (Rs 90,000 per Perch) in the Kotte U.C. area.

STUDY LIMITATIONS

The project team worked with limited information as well as data gaps that limit the accuracy of this prefeasibility study. The most important constraints included:

- Recent official (census) population projections are not available. The latest official census was performed in 1980.

- Recent aerial photographs were not available. The most recent aerial photographs available were from 1982.

- Only maps developed from aerial photography from 1982 in scale of 1:1000 contours were used. More recent topographic data would have been desirable.

We recommend the following additional work to complete the Feasibility Study and Master Plan for Kotte U.C.:

- Water Quality Monitoring and Sampling Program
- Comprehensive Community Survey
- Environmental Assessment
- Public Participation Plan
- More Detailed Financial Plan
- Pre-qualification Package
- Municipal Code for On-site Systems

The scopes of work for conducting the above activities are presented in Annex 3.

SECTION 1 - INTRODUCTION

1.1 GENERAL

Sri Jayawardenepura Kotte covers 4227 hectares which includes the administrative areas of three Local Authorities – Kotte Urban Council, Battaramulla Unit of Kaduwela Pradeshiya Sabha, and the northern area of the Maharagama Pradeshiya Sabha. The estimated population of the capital city area is currently 244,000.

The Development Plan of Kotte currently being revised by the Urban Development Authority (UDA). This plan will take into consideration the current development trend and future needs of the city. One of the main constraints for large scale developments is the provision of sewerage infrastructure facilities. With the exception of the Parliament and a local hospital, the entire area does not have sewerage infrastructure facilities. The current methods of wastewater and excreta disposal include a variety of on-site systems, such as: latrines, soakage pits, septic tanks, etc. The hydrogeologic conditions of many sectors of the study area may not be suitable for such on-site disposal systems, creating a concern for significant adverse effects on public health and environmental conditions in the area. Moreover, as many businesses and government agencies continue to migrate to this new growth area, the potential for adverse public health and environmental conditions increases.

In April of 1996, USAID initiated a project to assist the UDA in evaluating the existing conditions at Sri Jayawardenepura Kotte in order to define a planning strategy for properly managing the wastewater and excreta disposal. The project personnel from this initiative have identified the immediate need for a site-specific survey of the study area in order to properly assess the existing conditions and develop the appropriate strategy. There is sufficient information for the Kotte Urban Council area to allow for evaluating the existing situation. There is very little information, however, for the newer urban expansion areas of the Battaramulla Unit and the Maharagama sector that is within the boundaries of Kotte.

1.2 OBJECTIVE AND SCOPE OF SERVICES

The main objective of this effort is to undertake a pre-feasibility study and propose short-term and long-term strategies for the provision of sewerage infrastructure facilities for Sri Jayawardenepura Kotte in order to accommodate the future demand and facilitate the implementation of the UDA's Development Plan.

This effort is expected to:

- Study the existing land use and population distribution pattern as well as the UDA's development Plan for the study area in order to determine the sewerage requirements.

- Review the previous proposals and plans prepared for sewerage disposal scheme for the Kotte area.

- Identify short-term and long-term options available for safe disposal of sewerage in Kotte.

- Prepare a conceptual design proposal and preliminary estimates for an economically viable, technically feasible and environmentally acceptable sewerage disposal system and also identify priority areas for implementation according to the present and future sewerage requirements.

The proposed strategy should be formulated taking into consideration the on-going and proposed activities in respect to sewerage infrastructure improvements in the city of Colombo.

1.3 STUDY LIMITATIONS

The project team had to work with very limited information as well as data gaps that limit the accuracy of this prefeasibility study. The most important constraints included:

- Recent official (census) population projections are not available. The latest official census was performed in 1980.

- Recent aerial photographs were not available. The most recent aerial photographs available were from 1982.

- Topographic data used is adequate for the feasibility study level. However, a site-specific survey needs to be conducted for final design.

Comprehensive community survey providing information regarding: (1) existing conditions of the on-site systems; (2) socio-economic conditions to assess the willingness to pay for better sanitation conditions; (3) soil conditions and seasonal water table elevation to assess the suitability and adequacy of the existing systems.

SECTION 2 - THE PROJECT AREA's CHARACTERISTICS AND EXISTING CONDITIONS

2.1 PROJECT AREA

The project area is Sri Jayawardenepura Kotte which is the capital city of Sri Lanka. It is located east of Colombo and the area covers 4227 hectares which includes the administrative areas of three Local Authorities – Kotte Urban Council (U.C.), Battaramulla Unit of Kaduwela Pradeshiya Sabha, and the northern area of the Maharagama Pradeshiya Sabha. Due to the lack of site-specific data for both Battaramulla and Maharagama, these areas are excluded from the feasibility study and only the Kotte U.C. will be considered. **Figure 2-1** presents the general location and boundaries of the Kotte U.C. area. The Kotte U.C. area is the most densely populated area. The Kotte U.C. has an area of 1,690 hectares.

2.2 PHYSICAL CHARACTERISTICS

The project area is the coastal plain which extends from the shore of the Indian Ocean inland to the Central Highlands. About 90 percent of the land is less than 15 m above mean sea level (MSL). About 15 percent of the area within the study area boundary comprises lakes, water courses and marsh land. The flat nature of the land makes surface drainage difficult and increases the costs of installing conventional sewerage systems. Since large areas of land are only a few meters above mean sea level, groundwater levels are close to the surface, a situation which can cause problems for on-site disposal systems and lead to groundwater pollution.

2.3 CLIMATE

The study area lies in the wet zone of Sri Lanka. The heaviest rains are associated with the South West Monsoons and usually occur during the period immediately preceding and following the mid-May to September monsoons. Average precipitation is 2000-2500 mm per year. Evaporation exceeds rainfall only in January, February and March.

The daily mean temperature in the study area varies from 26°C to 29 °C. The highest mean daily maximum of 31.5°C occurs in April and the lowest mean daily minimum of 22.3°C in January. The highest day temperatures generally occur between 12.00 and 15.00 hours and the lowest between 05.00 and 06.00 hours. The climate has positive and negative implications for wastewater and sanitation. The continuous high temperatures and abundant sunlight promotes a high level of biological activity in natural systems receiving untreated wastewater. The long dry periods have a negative impact since there is insufficient flow in the urban canals and lakes to enable these natural systems to assimilate the waste loads imposed on them. Also, during low flow conditions, the water table aquifer discharges into the surface waters and contributes to non-point sources of pollution derived from on-site systems (such as: latrines, septic tanks and seepage pits).

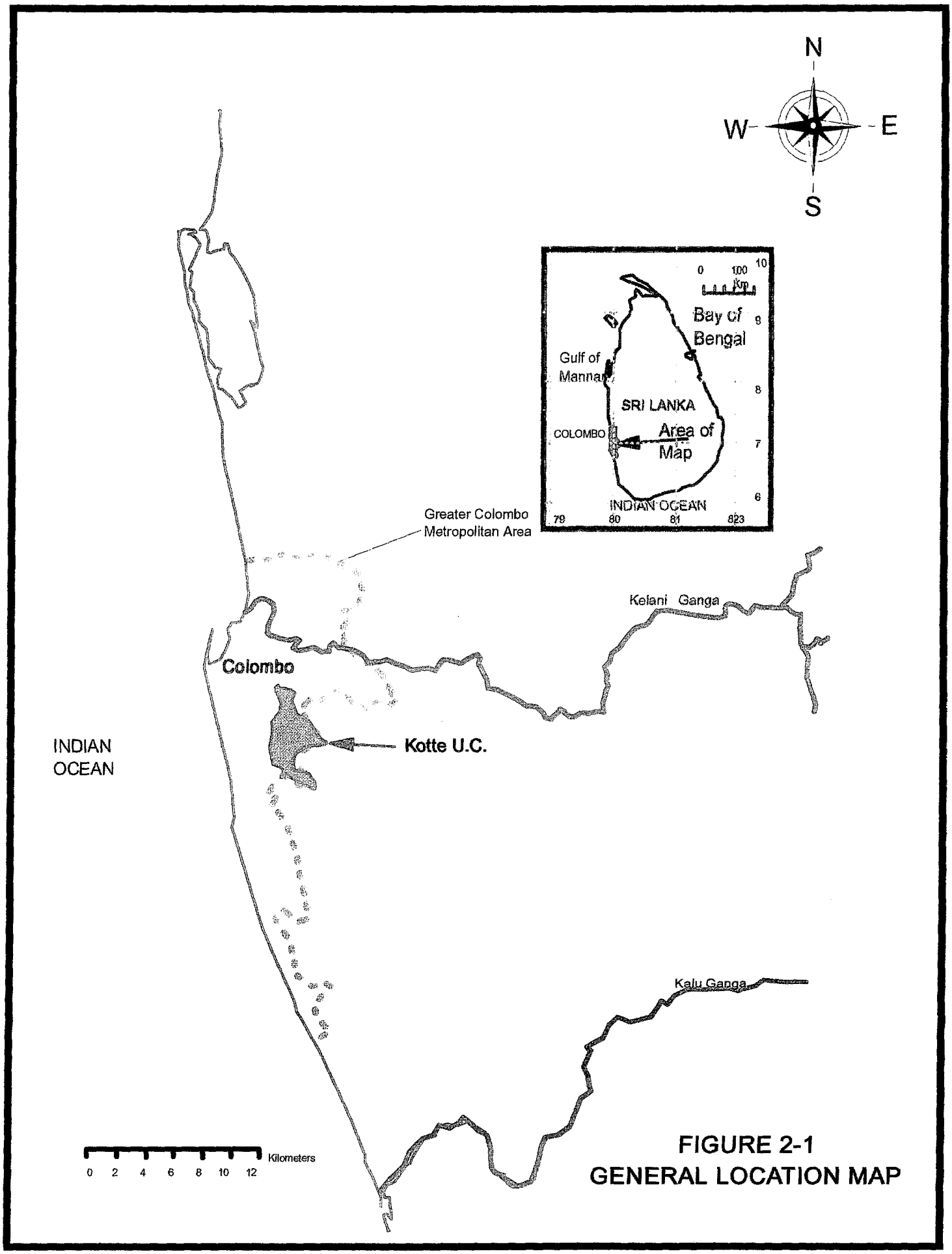


FIGURE 2-1
GENERAL LOCATION MAP

2.4 POLITICAL SETTING

The Government of Sri Lanka functions under a democratically elected parliament, an executive presidency and a president-appointed cabinet. Until recently, the main political subdivisions were the 24 Districts, each headed by a government agent who was appointed by the Ministry of Public Affairs. In 1987, the Thirteenth Amendment to the Constitution was enacted: this provided for the distribution of power from the Central Government to nine Provincial Councils. Each Provincial Council has a president-appointed governor who is responsible for appointing a Chief Minister. The Governor, on the advice of the Chief Minister, also appoints other ministers from the elected members of the Provincial Council.

Local Authorities comprise the municipal councils (10), the urban councils (133) and Pradeshiya Sabhas (194), which correspond to town and village councils. The Kotte UC is an urban council, and Battaramulla Unit of Kaduwela and the sector of Maharagama area are a Pradeshiya Sabha. Local government is included in the Provincial Council List of the Thirteenth Amendment, but the list also states that the local authorities retain the powers vested in them under existing laws. In effect, the implementation of the Thirteenth Amendment is still in progress. Inevitably, there will be a transition while the precise jurisdictions of the Provinces and the local authorities are determined.

2.5 KEY SOCIO-ECONOMIC FACTORS

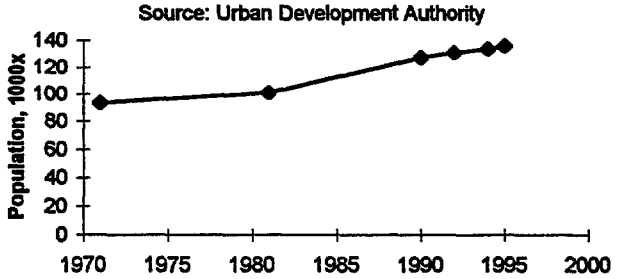
2.5.1 Economic Conditions

In general, despite the internal civil conflicts in Sri Lanka, the nation has one of the fastest growing economies in Asia. Site-specific information will be collected in the areawide survey proposed in Annex 3.

2.5.2 Population

The 1996 population of the Kotte U.C. area is estimated at about 139,300 people. The current annual rate of population growth is estimated to range from 2.6 to 3.2 percent. The historic population data is presented in **Figure 2-2.** Construction of high rise buildings and condominiums is growing. This population growth rate (or a higher rate) is expected to continue as more government offices and private businesses move to the Kotte area. In addition, as the price of land continues to rise, the tendency for high rise construction will increase.

FIGURE 2-2 POPULATION GROWTH FOR KOTTE U.C.1970-1996
Source: Urban Development Authority

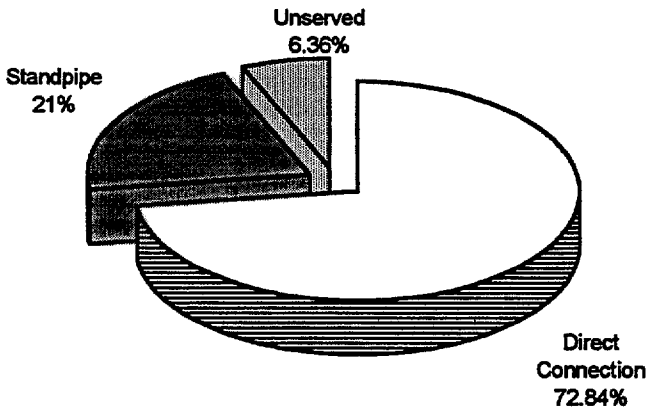


Recently, in the 30 month period from 1994 to mid-1996 the following new construction was registered in the Kotte U.C.:

1192 Residential buildings
113 Commercial/Industrial
12 Public sector buildings

2.5.3 Water Supply

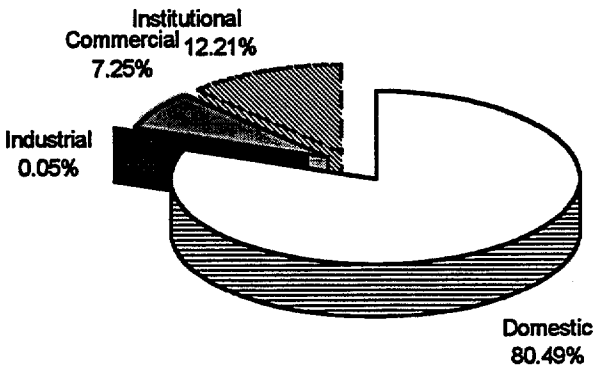
FIGURE 2-3 WATER SERVICE POPULATION FOR KOTTE U.C., 1992
Source: National Water, Sewerage and Drainage Board



In 1992, about 93.6 percent of the population in the Kotte UC area had metered water service, of which 20.8 percent had a standpipe and the remaining had a direct connection. **Figure 2-3** shows the water service distribution and **Figure 2-4** presents the categories of users. This figure shows that 92.7 percent of the water use in the area is either domestic or institutional. The domestic use is about 80.5 percent. The commercial and industrial water use is very small and accounts for about 7.3 percent. Current use categories are expected to be in the same range. Several residents in the area have their own wells and in some cases the wells are the only source of water supply.

FIGURE 2-4 Existing Water Uses In Kotte U.C., 1992

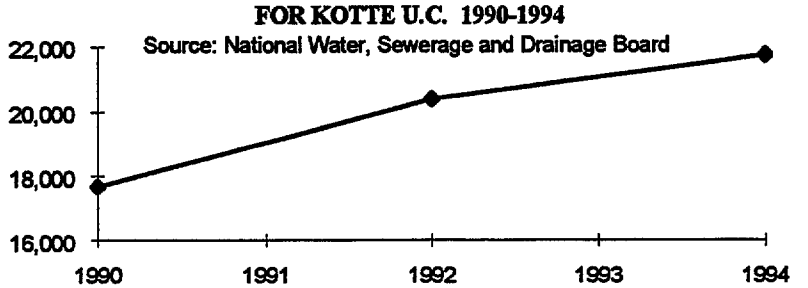
Source: National Water, Sewer and Drainage Board



The historic water consumption data is presented in **Figure 2-5.** The current water consumption for the Kotte U.C. is estimated to be in the range of about 22,300 m^3/day. The unit unaccounted for water (UFW) for the Kotte area is estimated at about 21 percent. Compared to other areas of the world this is a very good control of water losses water consumption rate is estimated at about 160 liters per capita per day (lpcd).

FIGURE 2-5 HISTORIC ACCOUNTED-FOR WATER CONSUMPTION FOR KOTTE U.C. 1990-1994

Source: National Water, Sewerage and Drainage Board



2.5.4 Wastewater and Excreta Management

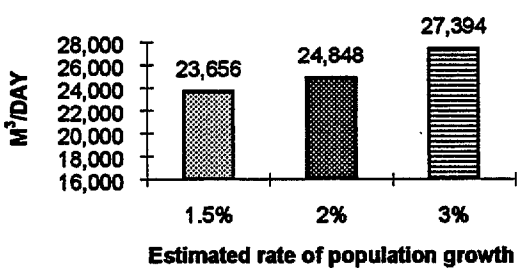
There is no piped sewage in the Kotte U.C. area. All systems are on-site and include, among others:

- Open pits
- Latrines
- Water sealed latrines
- Seepage pits
- Septic tanks

Figure 2-6 shows several variations of possible on-site systems. Very limited site-specific information about the on-site systems is available. A recent survey of 100 homes conducted by the Kotte U.C. shows that 68 percent of the homes use a one compartment septic tank with soakage pit. The remaining 11 percent of the homes surveyed use either latrines (several variations) or have their sewage discharged directly to the nearby canal.

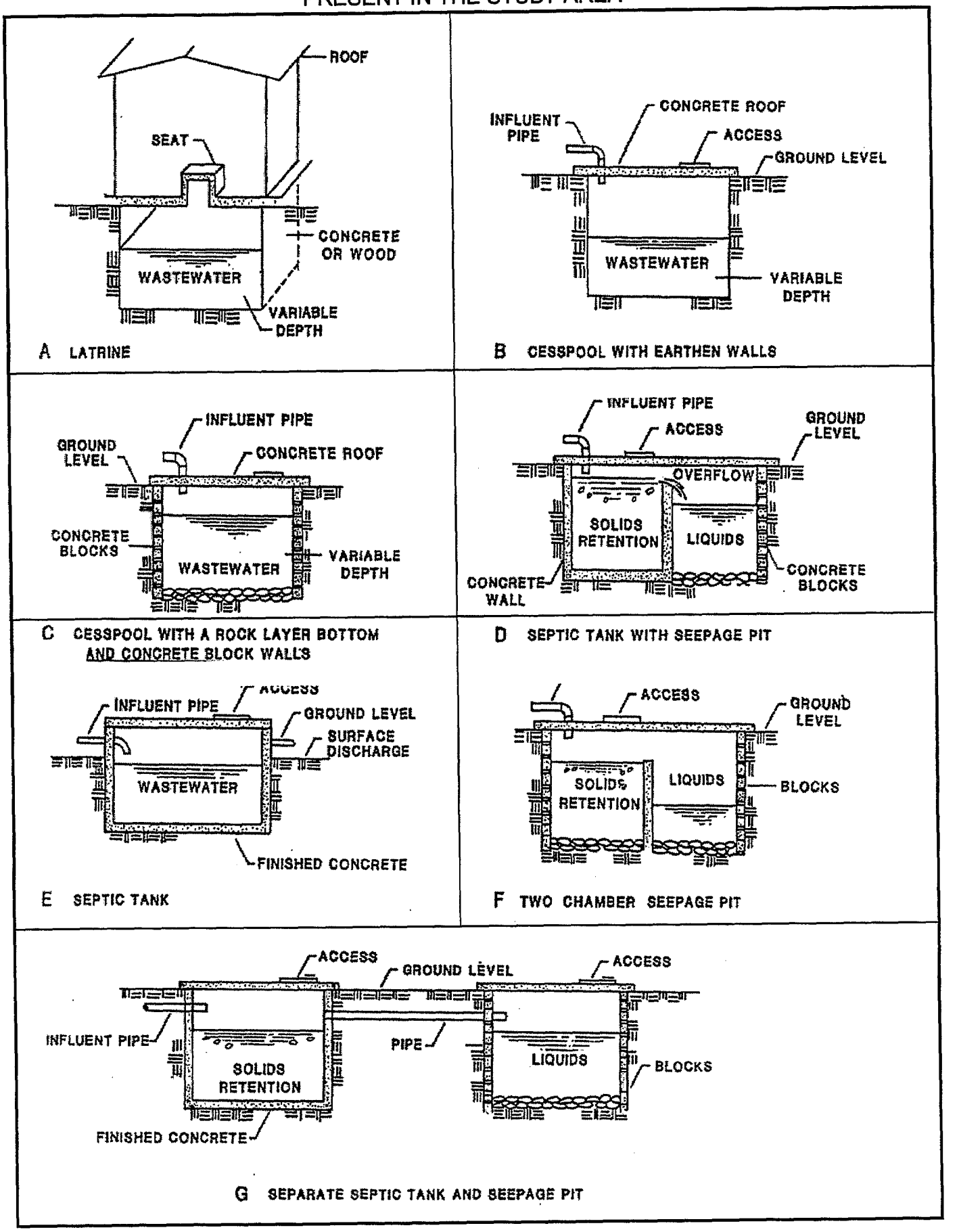
In general, the existing systems have a poor design and lack a soil adsorption system. There are no local or national ordinances or codes specifying the proper design of onsite sanitation systems. Some homeowners discharge only the toilet water to the septic tank and the gray waters are discharged to the ground surface. In some instances, the septic tank outlet discharges to the ground surface or to a nearby body of water.

FIGURE 2-7 ESTIMATED WASTEWATER VOLUME FOR KOTTE U.C. - 1996



As part of this report, the current wastewater volume generated in the study area was estimated. As shown on **Figure 2-7**, the possible wastewater generation in the study area ranges from 23,656 to 27,394 m^3/day. This is based on actual water consumption records and an estimated population growth rate ranging from 1.5 to 3.0 percent. This means that currently about 8.6 to 10.0 million cubic meters of sewage per year are discharged to the subsurface and, in some instances, directly into the surface bodies of water. It is possible that a large quantity of the wastewater ends up in the nearby canals and marshlands via runoff or seepage through the soil. Although water quality data is not available, the surface waters in the Kotte U.C. area exhibit a large quantity of aquatic plants, which indicate the presence of high levels of nutrients, such as phosphorous and nitrogen, which are derived from human wastes.

FIGURE 2-6 POSSIBLE TYPES OF ON-SITE SYSTEMS PRESENT IN THE STUDY AREA



2.5.5 Public Health and the Environment

The current situation regarding inadequate sanitation practices poses a serious threat to the public health and the environment. This threat is anticipated to increase as the population density increases in this area. The following water borne diseases have been reported by the Health Department in the study area:

- Viral Hepatitis
- Intestinal infections- diarrheal diseases
- Dengue fever
- Japanese Encephalitis
- Leptospirosis
- Malaria
- Cholera

SECTION 3. FUTURE SITUATION

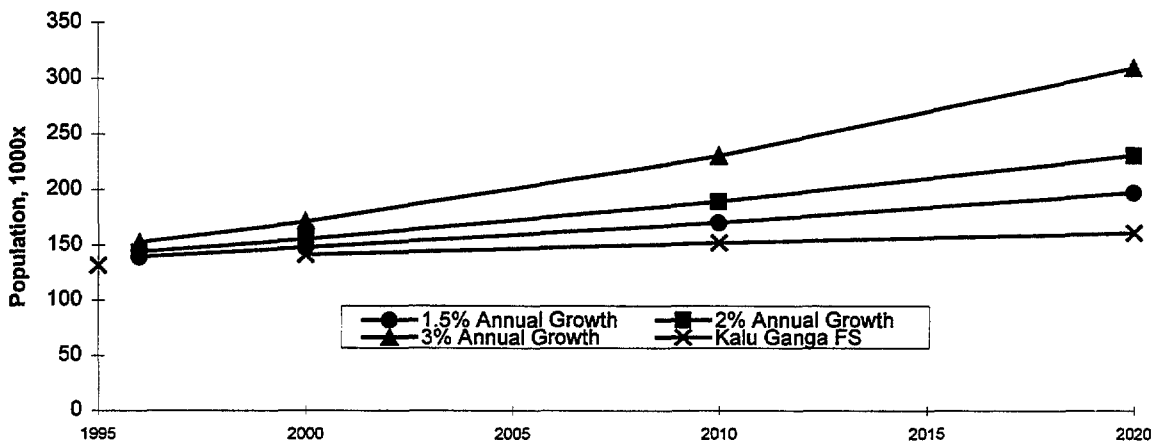
3.1 ECONOMIC CONDITIONS

Sri Lanka's economic future is very promising provided the domestic conflicts are resolved. Currently, the nation has one of the fastest growing economies in Asia and its growth is expected to be sustainable. One area being targeted for further development is "Eco-Tourism." However, in order to be able to draw tourists from Australia, Asia, and Europe, the basic infrastructure of transportation, communications, water and sanitation must be upgraded significantly.

3.2 POPULATION

The population of the Kotte U.C. Area is currently estimated at about 139,300 people. The current annual rate of population growth is estimated at 2.6 percent. **Figure 3-1** presents the population estimates developed for this study. These estimates include an analysis of several potential growth scenarios at rates of 1.5, 2.0 and 3.0 percent per year. In addition, a lower rate of population growth was estimated for the Water Master Plan of the Kalu Ganga Drainage Basin.

FIGURE 3-1 POPULATION PROJECTIONS FOR KOTTE U.C. 1996-2020



A growth rate of 2.0 percent per year is believed to be most representative for this effort due to the fact that previous studies (Greater Colombo Area Water Master Plan) have considered some areas in Kotte U.C. to be saturated or near saturation. However, with the tendency in the area for a growing number of high rise building and condominiums, it is anticipated that a higher growth rate will be experienced as more land currently used for single family units is converted to multifamily construction. In addition, as the price of land continues to rise, the tendency for high rise construction and more densely populated areas will increase.

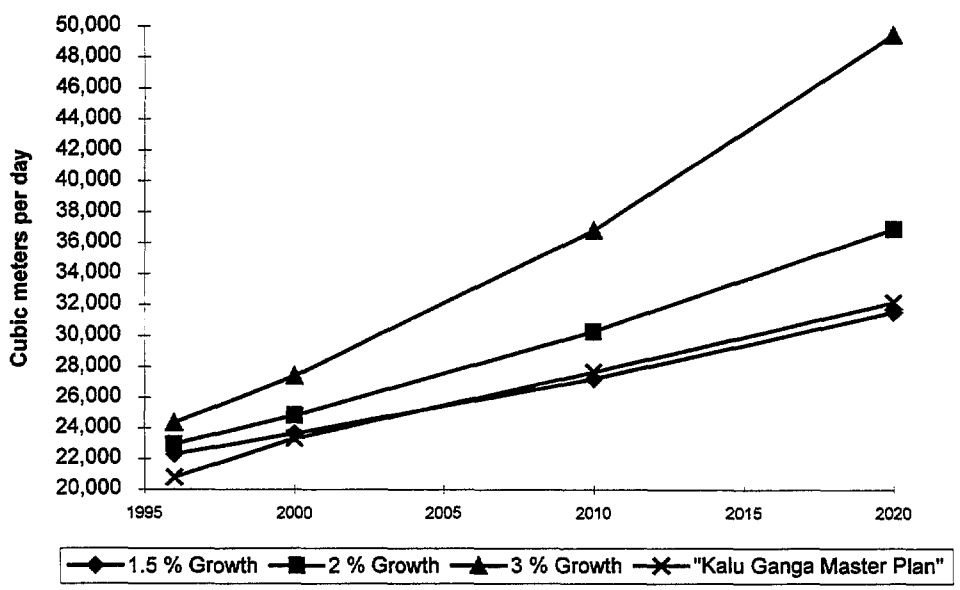
3.3 WATER USE

Estimating future water demand involves determining the future unit rate of water consumption liters per capita per day (lpcd) and the population. In order to estimate future water consumption, we have assumed a daily unit water consumption rate of 160 lpcd. This corresponds to the actual measured water consumption in the area (based on the National Water, Sewerage and Drainage Board records). Based on this, and using future population growth scenarios of 1.5, 2.0 and 3.0 percent, the future water uses from 1996-2020 is estimated and presented in **Figure 3-2**. This figure also includes the water use projections presented in the Greater Colombo Area Water Master Plan (Kalu Ganga Drainage Basin), which includes Kotte U.C. This Water Master Plan uses the following unit rates:

Year	lpcd
1995	158
2000	165
2010	182
2020	200

The resulting future water use is similar to that of the 1.5% scenario with 160 lpcd.

FIGURE 3-2 PROJECTED WATER USE FOR KOTTE U.C. 1996-2020 (Based on 160 liters/capita-day)



The future water consumption estimates are summarized in the following table:

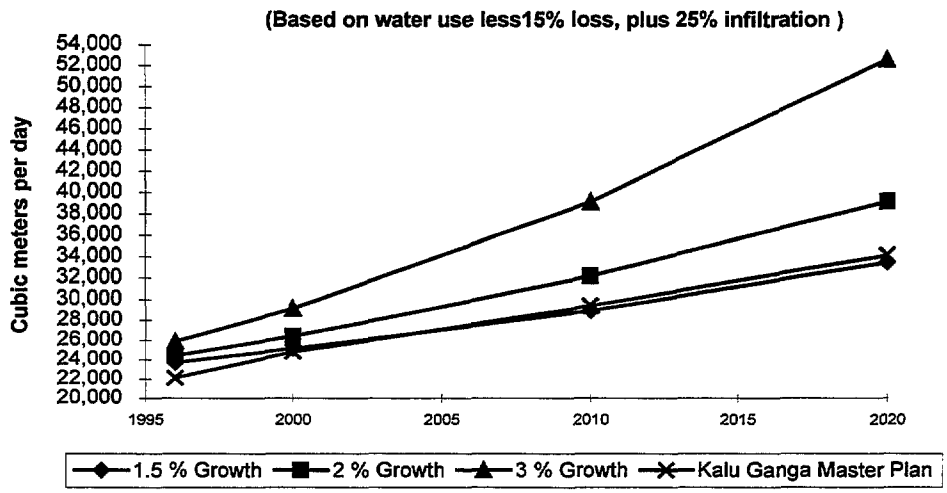
Year	1.5% Growth	2% Growth	3% Growth	Kalu Ganga Master Plan
1996	22,289	22,956	24,340	20,777
2000	23,656	24,848	27,394	23,331
2010	27,227	30,290	36,816	27,664
2020	31,549	36,923	49,477	32,180
all in m^3/day				

3.4 WASTEWATER AND EXCRETA MANAGEMENT

The wastewater volume generated in the study area will increase significantly, as new high rise and multifamily developments increase in the Kotte U.C. **Figure 3-3** presents various projections of future daily wastewater volumes that could be generated in the Kotte U.C. area. These volumes are based on growth scenarios of 1.5, 2.0 and 3.0 percent, the future water uses from 1996-2020. The water use volume is reduced by 15 percent to account for water loss by consumption (retained in food, evaporation in cloth washing, etc.) and increased by 25 percent to account for infiltration in the sewer pipes that convey the wastewater. In addition to the three growth scenarios, a fourth scenario was added that takes into account the water use projections for the Greater Colombo Area Water Master Plan (Kalu Ganga Drainage Basin) which includes Kotte U.C.

FIGURE 3-3 PROJECTED WASTEWATER GENERATION FOR KOTTE U.C. 1996-2020

(Based on water use less15% loss, plus 25% infiltration)



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Based on the assessment of the area, taking in consideration the growth patterns, type of new construction, price of land, etc., we believe that the potential for growth in the area is greater than anticipated in the Water Master Plan. Therefore, for the purpose of this study, we have selected a scenario of 2 percent growth per year.

3.5 PUBLIC HEALTH AND THE ENVIRONMENT

Current sanitation practices have been carried on without ordinances or codes that require specific design for onsite disposal systems. Consequently, most of the builders have put in place inadequate or sub-standard systems. Moreover, as future population density increases, this situation poses a serious threat to the public health and the environment if no corrective measures are taken.

SECTION 4. ASSESSMENT OF WASTEWATER AND EXCRETA MANAGEMENT OPTIONS

Several technologies may provide adequate wastewater treatment and disposal for the current and projected population of the study area. This section outlines the range of technologies under consideration and establishes criteria for judging or screening the technologies.

The screening criteria include technical, regulatory, and institutional feasibility and requirements. After preliminary screening, subsequent sections consider the most viable options in greater detail. **Figure 4-1** presents the general technology development scheme followed in this chapter.

The technologies considered fall into one of the following groups:

- On-site treatment and disposal
- Collection and transport for centralized treatment
- Centralized treatment and disposal
- Wastewater flow reduction

A discussion of each group and its associated technologies follows.

4.1 ON-SITE TREATMENT AND DISPOSAL

Based on preliminary information, Figure 2-6 displays the seven predominant systems currently used in the study area. The septic tanks are either one or two chamber units. Liquids from these units percolate into the ground through a seepage pit or via an earthen or concrete block wall and through rock bottoms. Drainage fields are not used. Where septic tanks and cesspools are used, the maintenance is usually neglected until problems, such as odors and surface break-out, are noticeable.

The current wastewater treatment and disposal practices present a serious potential for surface water or groundwater contamination. Moreover, as the study area population expands, the environmental and health hazards from inadequately designed and maintained on-site systems will most likely increase to a point were the surface water and groundwater bodies could be significantly deteriorated. Under certain conditions, individual treatment and disposal systems can be used effectively for disposing of wastewaters.

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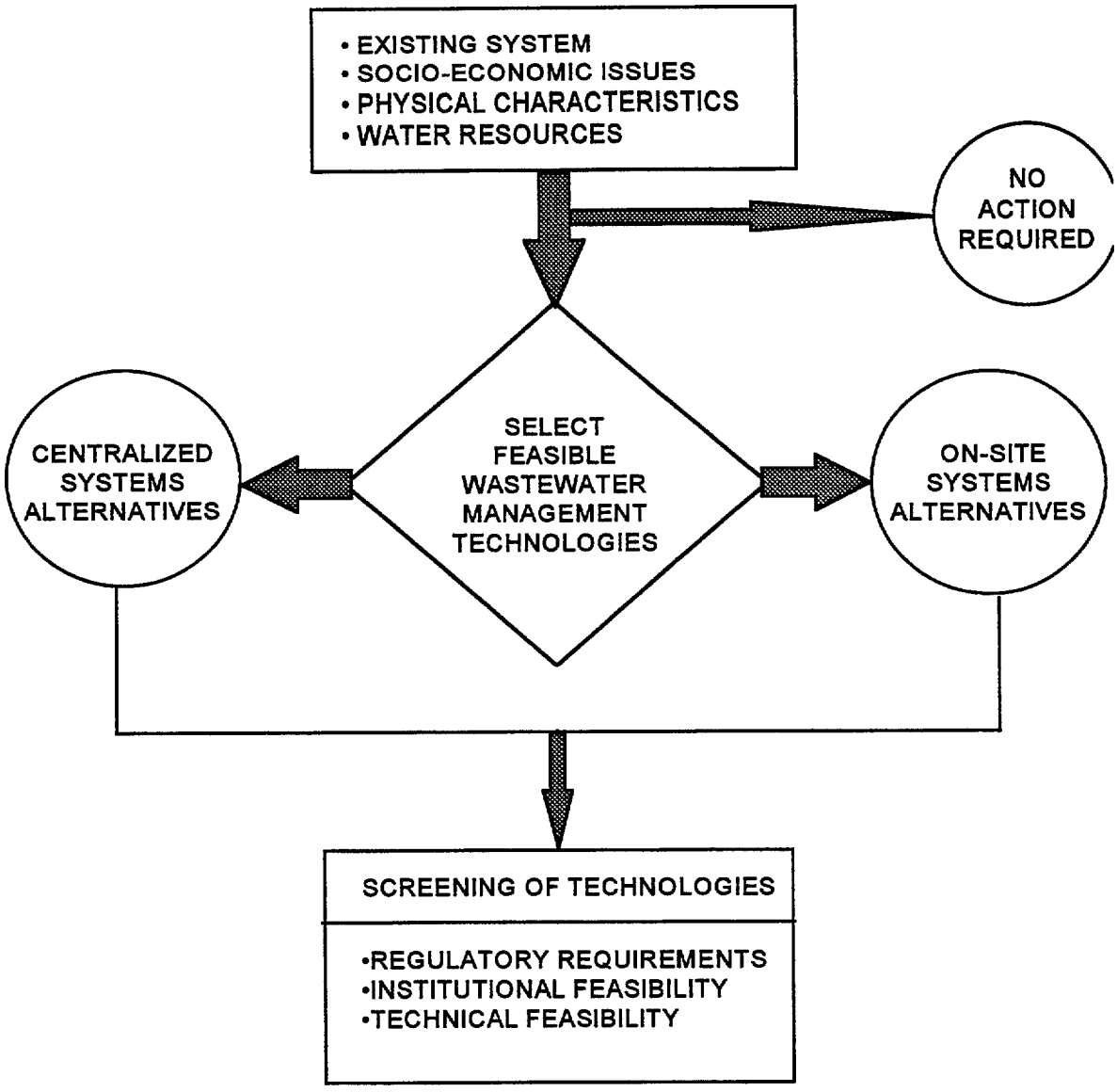
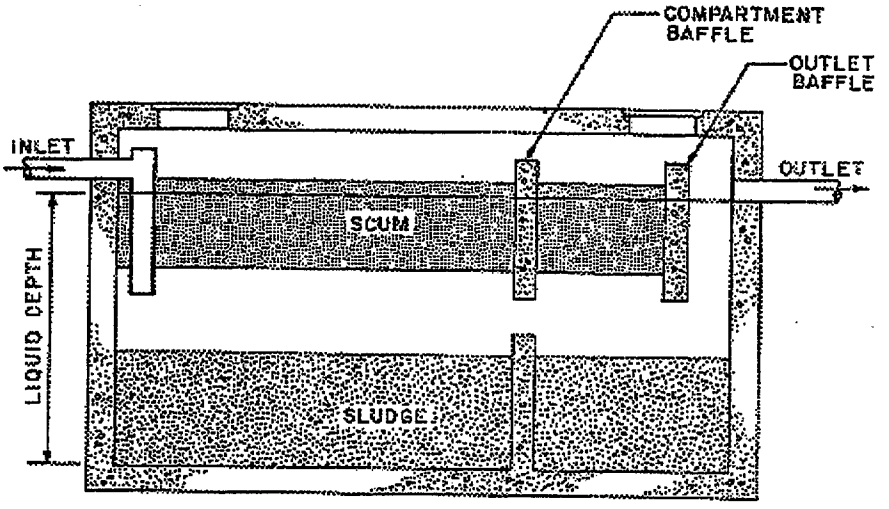
FIGURE 4-1 SCHEME FOR EVALUATION OF TECHNOLOGIES



Ranging from simple seepage pits to relatively complex aerobic treatment units, these small systems, if applied under recommended conditions and properly maintained, are a vital element in protecting public health and the environment in rural or sparsely developed areas in many parts of the world. However, it is important to understand the characteristics and limitations of these systems in order to determine their effectiveness in the treatment and disposal of wastewaters.

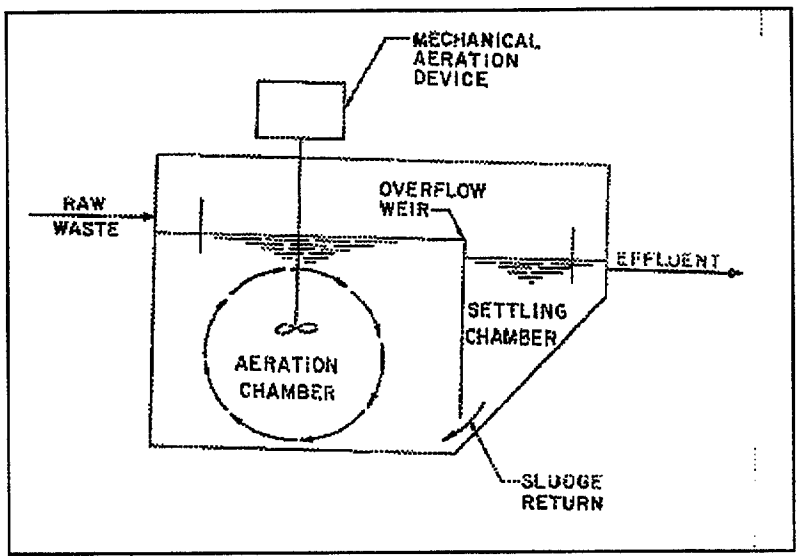
4.1.1 On-Site Treatment Systems

The on-site treatment methods considered for the study area are: (1) septic tanks; (2) aerobic treatment systems; (3) holding tanks; and (4) sand filter systems.



Septic tanks - A septic tank is defined as a water-tight, covered receptacle designed and constructed to receive the discharge of sewage from a building sewer, separate solids from the liquid, digest organic matter and store digested solids through a period of detention, and allow the clarified liquids to discharge for final disposal. One-compartment tanks, which are predominant in the study area, are essentially identical to the two-compartment unit shown in this sketch, with two exceptions: (1) there is no compartment baffle, and (2) the outlet pipe extends downward into the clear space as the inlet pipe does in the sketch. In a septic tank, primary treatment is achieved through gravity separation of liquid and solids. Septic tank effluent is therefore of a lower quality than that which can be achieved with higher degrees of treatment, but a high quality effluent is not required if final disposal is to a subsurface disposal field. The tank serves to remove scum, grease, and settleable solids from raw sewage to prevent these materials from clogging the disposal field. Septic tank performance in terms of percentage removals of influent biochemical oxygen demand (BOD) and total suspended solids (TSS), is generally rated at 50 to 60 percent removal of BOD and 60 to 70 percent removal of TSS.

Aerobic Sewage Treatment Systems - Aerobic, or mechanical oxidation systems, are treatment units which can be used for individual homes, for home clusters, multifamily units, or as a community system. These systems provide mechanical contact between raw sewage and air and then removes suspended solids. The most commonly available systems of this type involve extended aeration, retaining the sewage long enough to convert most of the waste matter into carbon dioxide and water. However, over a period of time, there is a buildup of sludge in the treatment tank, just as there is in a septic tank; the sludge must be removed to permit continued acceptable performance. A typical two

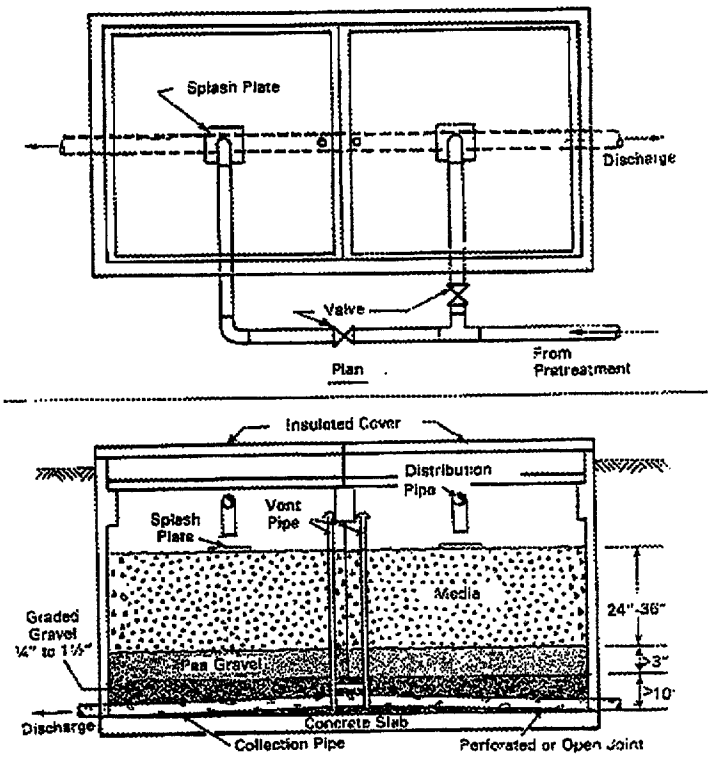


chamber extended aeration unit is shown in adjacent sketch. When properly operated and maintained, the extended aeration process is capable of removing approximately 90 percent of the dissolved organic material and suspended solids from raw wastewater and can reduce 90 percent of the coliform bacterial populations. While these systems achieve a high quality effluent, extended aeration units require power for mixing and regular attendance for operation and maintenance. They are also more susceptible to upset due to shock loadings of concentrated wastes and harmful chemicals than are septic tanks. Effluent quality from extended aeration plants can therefore be highly variable unless special precautions are taken. The effluent can be discharged by either surface or subsurface methods. If discharged to surface waters the effluent must be disinfected.

Holding Tanks - Holding tanks can be used to prevent contamination of the environment . They consist of a watertight tank constructed without an outlet that could receive the black water (toilet wastewaters) stream only, or the combination of the black and gray water streams. When the tank fills, an independent or municipal septage hauler would be contacted to pump out the holding tank contents and to dispose of the-waste in a regional treatment plant or special septage handling and treatment facilities. Thus, both individual and community holding tank systems would require extremely large tanks to accommodate the combined wastewater volumes. When compared with other options, holding tank systems have consistently resulted in the most expensive alternative and should only be considered when there are no other possible alternatives. Therefore, it will not be further evaluated unless all other potentially effective alternatives are not feasible.

Sand Filter Systems - These systems are used to polish the effluent from a septic tank or from aerobic treatment process prior to disposal. Disposal is generally accomplished by a drainfield or surface waters. Two sand filter types, the free access and buried sand filters, are being considered for the study area. The attached figure show a plan view and a cross-section of both systems respectively. The free access filter will be considered for community systems, while the buried type would be used for individual homes. Both systems would be used as substitutes for soil absorption trenches and must be followed by disinfection since in these systems coliform bacteria are not usually destroyed below the required concentrations for surface discharge.

TYPICAL FREE ACCESS INTERMITTENT FILTER



Source: Onsite Wastewater Treatment and Disposal Systems, EPA Technology Transfer, Design Manual, EPA-625/1-80-012

4.1.2 On-Site Disposal Systems

Alternative on-site disposal systems considered for the study area are: (1) conventional drainfields; (2) capping fill drainfields; (3) evapotranspiration absorption (ETA) beds; (4) mounded disposal beds; and (5) seepage pits.

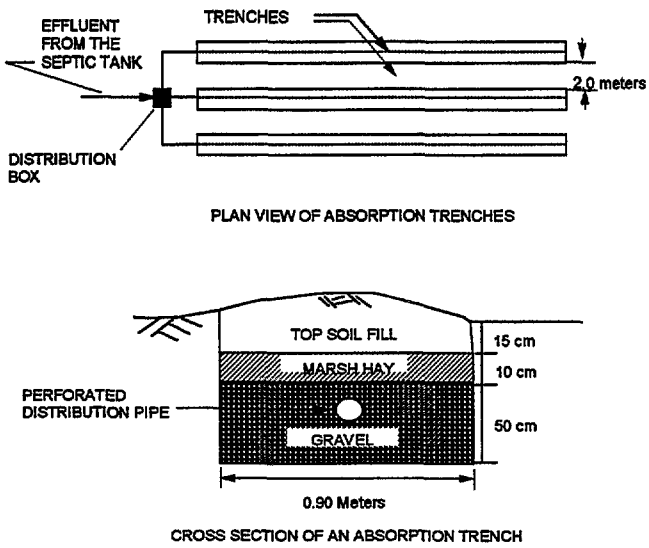
Conventional Soil Absorption System - The conventional drainfield or soil absorption trench consists of 2- to 3-foot lengths of open joint sewer pipes, or perforated pipe with tight joints, laid in trenches. Important factors affecting soil absorption systems (SAS) performance are: percolative capacity, infiltrative capacity, soil particle size, and loading rate.

Percolative capacity is defined as the measure of the rate at which effluent can be transmitted through the soil pores. A percolation test can be used to determine if the soil will hold a SAS or not. This factor, however, does not control the long-term capacity of the SAS. Percolation rates of one hundred and twenty (120) minutes per inch or faster obtained with carefully performed standard percolation tests, indicate that the soil will have sufficient infiltrative capacity to support a SAS.

The infiltrative capacity is a measure of the rate at which effluent can enter the soil through the surface-it is applied. It has been demonstrated that the infiltrative capacity of the liquid-soil interface is the factor that controls the long-term capacity of the SAS. The major reduction of infiltrative capacity results from the formation of an organic mat at the liquid-soil interface. This zone is also where the major biological activity, suspended material deposition, and bacterial buildup occurs.

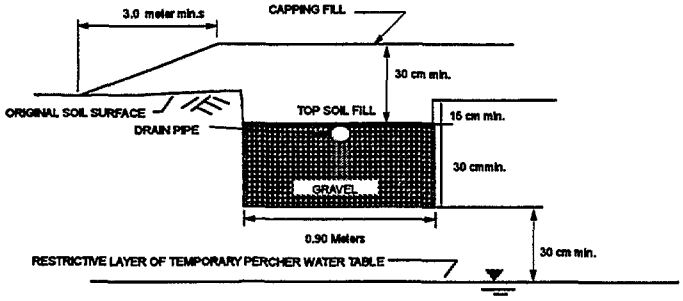
Therefore, continual buildup of material will eventually cause SAS to fail. The only procedure demonstrated to reestablish the infiltration activity is resting the system. This can be accomplished by providing dual systems alternatively operated.

The soil particle size is a soil characteristic which influences both the percolative and infiltrative capacity. The common definition of a soil particle size is "effective size", which describes a soil containing 10 percent by weight of particles smaller than the standard size.



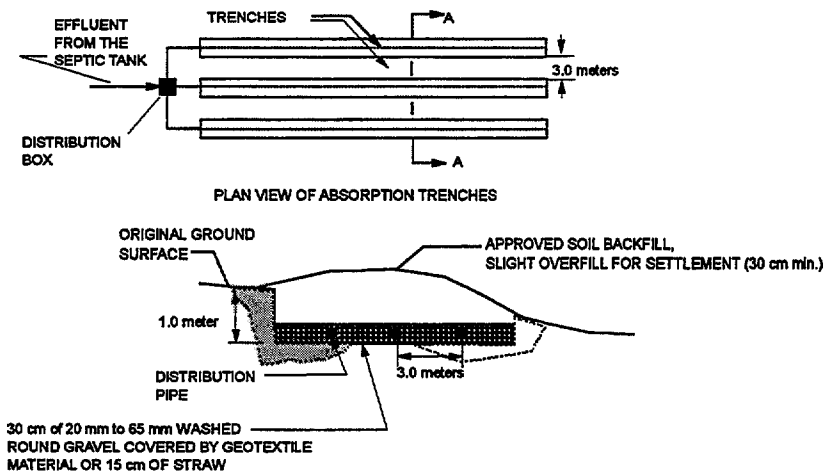
TYPICAL LAYOUT OF AN ABSORPTION TRENCH

The loading rate is expressed as the cubic meters of liquid applied daily per square meter of surface area. As previously discussed, intermittent dosing, with alternative periods of use and rest, can materially lengthen the functional life of any drainfield. Intensive research of SAS infiltrative capacity, concludes that an infiltrative loading rate of 0.009 m^3/m^2-day (0.03 ft^3 per day per ft^2) of surface area can be considered an applicable conservative loading rate. Many different designs may be used in laying subsurface disposal fields. The choice may depend on the size and shape of the available disposal area, the capacity required, and the topography of the disposal area. The above figure shows a typical absorption trench layout. To provide the minimum required gravel depth and earth cover, the depth of the absorption trenches should be at least 50 cm. (21 inches). Additional depth may be needed for contour adjustment, extra aggregate under the tile, or other design purposes. The maintenance of a 1.21 meter (4-foot) separation between the bottom of the trench and the water table is required to minimize ground water contamination. It is important during construction to assure that the tile lines are surrounded by gravel.



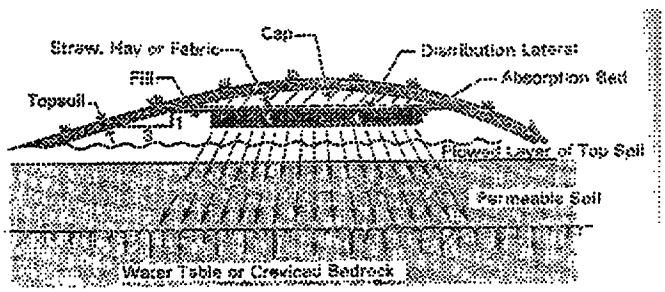
CAPPING FIELD DRAINFIELD

Capping Fill Drainfields - This system is a variation of the conventional absorption trench. The adjacent sketch provides a cross sectional view of a capping fill drainfield. As shown, the drainfield would be similar to a conventional drainfield except it would be constructed higher in the soil profile and a layer of fill material would be placed over the top of the absorption trench. Therefore, this system can sometimes be used in cases where groundwater and impervious or restrictive layers are too near the ground surface to meet regulations for conventional systems.



Evapotranspiration-Absorption (ETA) Beds - ETA beds use a combination of evaporation, vegetative plant transpiration, and soil absorption to dispose of the effluent from a conventional septic tank. As illustrated in the adjacent sketch, the effluent would enter a bed of coarse rock from which it would be absorbed into the soil in all directions. A portion of the liquid percolates downward into the ground, and the rest rises in the bed by capillary action to a level where it is consumed by plants on the bed surface or evaporates into the atmosphere. This system can only function properly when the evapotranspiration rate is well above the precipitation rate.

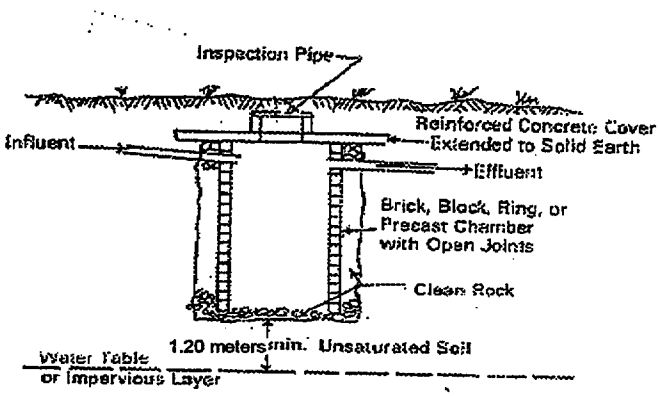
Mounded Disposal Beds - Mounded disposal beds are very similar to capping fill systems. The adjacent sketch a cross sectional view of a typical mound system. The primary difference is that for the mounded bed the drain line is constructed in the mound rather than at the ground surface. Care must be taken to ensure that waste does not migrate laterally out of the mound or out of the surface adjacent to the mound. The objective of keeping the effluent below ground is accomplished by using a clay barrier on the mound walls.



Cross Section of a Mound System for a Permeable Soil with High Groundwater or Shallow Crevicked Bedrock

Source: Onsite Wastewater Treatment and Disposal Systems: EPA Technology Transfer, Design Manual, EPA-625/1-80-012.

Seepage Pits - Seepage pits are deep excavations used for subsurface disposal of pretreated wastewater. They are the most common soil absorption system used in the study area and consist of a covered porous-walled chamber placed in the excavation and surrounded with gravel or crushed rock. Wastewater enters the chamber and is retained until it infiltrates the sidewalls of the excavation. The adjacent sketch shows a cross-section of a seepage pit.



Source: Onsite Wastewater Treatment and Disposal Systems. EPA Technology Transfer, Design Manual, EPA-625/1-80-012.

4.2 WASTEWATER COLLECTION SYSTEMS

4.2.1 Sewers

Description

Conventional wastewater collection systems generally consist of conventional gravity sewers carrying raw sewage by gravity. Gravity sewers are designed by traditional, conservative criteria based on several years of experience. Manholes are included to allow access for cleaning. Normally, the sewer pipes slope constantly downhill, but in adverse topography lift stations and force mains often must be included in the collection system to avoid excessive excavation or to reach a fixed elevation at the system's outfall.

Technology Status - Widely used for many years.

Applications - Conventional gravity sewers are best suited to densely populated service areas with a relatively constant, gentle slope toward a desirable treatment plant location.

Limitations - Conventional gravity sewers can be inordinately expensive where adverse slopes require deep excavation, many lift stations, or where the population density of the service area is low.

Performance - No treatment occurs in conventional gravity sewers except dilution by infiltration and inflow and a small amount of aeration.

Reliability - Conventional gravity sewers are ordinarily highly reliable. They often require periodic flushing or cleaning to remove deposits of solids and grease. Unlined concrete or cast iron pipes are subject to corrosion and may require expensive lining or replacement after a few years of service. Lift stations, usually associated with gravity sewers, require frequent maintenance and cleaning.

Environmental Impact - The environmental impact of conventional gravity sewers arises from their construction, the release of sewer gases, and the operation of the lift stations normally associated with them.

Design Considerations

Design Criteria - A typical average flow allowance for Sri Lanka is 0.2 m^3/cap-day. This estimate is based on 85 percent of the water consumption of 200 liters per capita per day plus a moderate infiltration of 25 percent. Alternatively, a separate allowance for infiltration and inflow can be estimated but site-specific information is not available. Sewers are designed to carry peak flow rates, usually calculated by multiplying the average flow by a peaking factor; a typical formula is:

$Q_{max}/Q_{ave} = (18+\sqrt{P})/(4+\sqrt{P})$

where P is the population in thousands (GLUMRB, 1978). This formula yields peaking factors ranging from about 4.2 for a service population of 100 to 2 for a population of 100,000. The minimum pipe diameter is typically 200 mm (8 in). This conservative criterion avoids the clogging of the sewer by large objects. Conventional gravity sewers are designed to avoid pressure flow at all times. They must also have sufficient downward slope to prevent the deposition of solids and grease. To this end, they are typically designed to provide a velocity of at least 0.6 m/sec when full. Manning's formula is typically used to calculate flows, slopes and velocities. The Manning equation is:

Table 4-1

Nominal Sewer Diameter (mm)	Minimum Slope (m/100 m)
200	0.40
230	0.33
250	0.28
300	0.22
400	0.14
450	0.12
500	0.10
600	0.08
700	0.067
900	0.046
1000	0.040

Adapted from: GLUMRB, 1978

$$V = \frac{R^{2/3} S^{1/2}}{n}, \text{ or}$$

$$Q = \frac{A R^{2/3} S^{1/2}}{n}$$

where:

V = velocity, m/s
n = coefficient of roughness
R = hydraulic radius, m (cross-sectional area of flow divided by the wet perimeter)
S = slope of the energy grade line, m/m
Q = Flow, m^3/sec
A = Cross-sectional area, m^2

Typical roughness coefficients range from .011 to .015 and average .013. The smoother the pipe the lower the n value. The minimum slopes used for sewers in the U.S. are summarized in **Table 4-1**.

Manholes are typically placed at the end of lines, at every change of slope, alignment, or diameter, and at least every 120 m for sewers up to 400 mm in diameter and every 150 m for sewers of 450 to 1000 mm .

Design for Life Safety - Confined space hazards and explosion hazards from sewer gases must be avoided. The principal point of human entry into conventional gravity sewers is the manhole. No one

should ever enter a manhole without a standby person at the surface, who should be in radio contact with rescue personnel trained and equipped to perform constrained space rescues. The concentrations of oxygen and toxic gases should be determined by a portable gas monitor before entry. A portable blower and air hose should be used to ventilate the manhole. A person entering the manhole should be on a harness attached to a hoist erected above the manhole. The standby person should be able to hoist the entering person out of the manhole even it the latter becomes unconscious.

Materials

Various pipe materials have been used in Sri Lanka and around the world, including vitrified clay, reinforced concrete, cast iron, ductile iron, polyvinyl chloride (PVC), and acrylonitrile-butadiene-styrene (ABS). The use of asbestos cement has declined due to the potential health hazards associated with asbestos fibers. In general, preferred sewer pipe materials for the country of Sri Lanka (based on price and availability) include:

vitrified clay,
reinforced concrete, and
polyvinyl chloride (PVC).

4.2.2 Force Mains

Description

A force main is a pipe carrying sewage under pressure. Such force mains typically have no service connections entering them.

Technology Status - Widely used for many years.

Applications - Force mains are used to transport sewage uphill to avoid excessive excavation in a predominantly gravity flow collection system. They may be required within the system or at its terminus to lift sewage to a treatment plant.

Limitations - Surge control is needed to avoid damage to pumps and piping from hydraulic transients (water hammer).

Performance - No treatment is achieved in force mains.

Design Considerations

Design Criteria - Fluid velocities must be capable of carrying all suspended matter and grease through force mains. For raw sewage, the minimum velocity is 0.6 m/s (2 ft/s); but at least 1.1 m/s is preferred. In systems carrying septic tank effluent, the minimum velocity can be about 0.3 m/s, because most of the suspended matter and grease has been removed in the septic tanks. To prevent

scouring of the force main by grit in raw sewage, and to prevent excessive head loss and surge control difficulties in all applications, the velocities should generally not exceed 2.4 m/s. The Hazen-Williams C factors used in the design of new systems range from 100 for small, unlined ductile iron to 150 for larger plastic pipe.

Reliability - Properly designed force mains are highly reliable. Some pipe materials, however, such as unlined concrete and cast iron, may be severely corroded or eroded after a few years and may need to be lined or replaced.

Environmental Impact - Force mains have minimal environmental impact, except during construction or in case of a line break.

Energy Consumption - The lift stations associated with force mains consume energy in pumping and maintenance.

Materials

Various force pipe materials have been used in Sri Lanka and around the world, including cast iron, ductile iron, steel pipe, reinforced concrete, and polyvinyl chloride (PVC). In general, preferred sewer pipe materials for Sri Lanka include:

cast iron
ductile iron
reinforced concrete, and
PVC.

Installation and Maintenance Costs

Construction costs vary widely, depending on pipe size, excavation depth, subsurface conditions, site accessibility, type of materials, and quality of installation. Operation and maintenance costs also vary widely and are difficult to estimate because both the O&M and accounting practices of the water authorities vary. In particular, it is not easy to determine what costs are incurred by different parts of the system (i.e., gravity mains, lift stations, force mains, etc.).

4.2.3 Sewage Pumping Stations

Description

A sewage pumping station (lift station) is a structure housing pumps that propel sewage to a higher elevation. Its primary components are inlet works; a wet well, in which incoming sewage is briefly stored; pumps; controls that turn the pumps on and off when the sewage in the wet well reaches specified elevations; and valves necessary to shut down the station for maintenance or repair. The pumps discharge into a force main, (pressurized sewer). Lift stations have been classified by capacity (WPCF, 1981) as shown in the adjacent table. They become increasingly complex as their capacity increases. Prefabricated stations are available up to about 400 L/s, but lift stations can be custom-designed and built in-place at any size.

Common Modifications - Lift stations can be designed with either conventional or submersible pumps. Conventional pumps require a dry well; only the pumps suction piping enters the wet well. Submersible pumps are designed to work submerged in liquid; therefore, they are placed in the wet well and the lift station requires no dry well. Submersible pumps are coupled to piping by quick-disconnect fittings, are mounted on guide rails, and are connected to a lifting chain so that they can be removed for service without the entry of maintenance persons into the wet well. Non-clog pumps capable of passing solid spheres up to 2 1/2 to 3 inches in diameter are typically used (GLUMRB, 1978). In very small stations, grinder pumps may be used. Submersible pumps are self-priming; some conventional pumps may require external priming by water or vacuum. When non-clog pumps are used, trash baskets or bar screens are used in the inlet works to remove solids too large to pass through the pumps. A wide variety of pumps have been used, including various types of centrifugal pumps, turbine pumps and Archimedes screw pumps.

Class	Capacity L/s	Capacity (gpm)
Very small	<6	<100
Small	6-20	100- 300
Medium	20- 200	300-3000
Large	>200	>3000

Lift stations should contain at least two pumps. The pumps are actuated by level controls mounted in the wet well. The most common type of level control is the mercury float switch; others include diaphragms, bubblers, electrodes, ultrasonic level detectors, and pressure transducers. In duplex stations, containing exactly two pumps, one is designated the lead pump and comes on first; the other is designated the lag pump and comes on only if the lead pump is unable to keep pace with the inflow of sewage. To equalize wear on the pumps, controls are set to alternate the lead and lag pumps, either at every pumping cycle or at a set time interval. In stations containing three or more pumps, the pumps may be set to come on in sequence. The pump off level is either the same for all pumps, or

they may be used to go off in reverse sequence. Alternatively, the third pump may be used as a standby or emergency pump, while the first two operate as in a duplex station.

Swing disc check valves, ball check valves, and other types of check valves are used to prevent backflow through the pumps. Plug valves, ball valves, or gate valves are typically used as shut-off valves to isolate a pump for maintenance or replacement. Telemetry can be used to monitor the operation of lift stations from a remote site.

Technology Status - Widely used for many years.

Application - Lift stations are used to pump sewage uphill to avoid excessive excavation. Extant data suggests that as more adverse topographies have been sewered, the frequency of lift stations in conventional gravity sewers has increased significantly.

Limitations - Lift stations must be located where they will not be subject to flooding or must be protected against it. Very small lift stations can be built in the street right-of-way, but larger stations may require a house lot or larger plot of land. Lift stations require electrical power, which can be supplied from nearby power lines or from a dedicated generator. In any case, a standby generator is required for continued operation in case the primary power source fails. Surge control is needed to avoid damage to pumps and piping from hydraulic transients (water hammer). Potentially lethal hazards to maintenance workers arise from toxic and explosive gases or oxygen deficiency in confined spaces. Ventilation is imperative if the wet well is large enough for human entry. Odors emanating from lift stations must be controlled. A variety of odor control techniques is available. Corrosion of all metal parts within a lift station can be severe.

All but the smallest lift stations should be inspected daily and require frequent preventive maintenance. Trash baskets and bar screens must be cleaned, and grease and sediment accumulations must be removed from the wet well before they foul the pumps and controls.

Performance - No treatment is achieved except for the removal of large objects from trash baskets or bar screens or the grinding of solids in lift stations using grinder pumps.

Design Considerations

Design Criteria - A lift station should have more than one pump, and the pumps must be capable of delivering maximum design flow with the largest pump out of service. The pumps must be sized for the full range of flow rates and heads expected; each pump should operate near its best efficiency point. Therefore, both maximum and minimum design flow must be carefully estimated.

Fluid velocities must be capable of transporting all suspended matter and grease through the pumps and pipes. For raw sewage, the minimum velocity is 0.6 m/s, but at least 1.0 m/s is preferred. In sewer systems carrying septic tank effluent, the minimum velocity can be 0.3 m/s or less, because most of

the suspended matter and grease has been removed in the septic tanks. Minimum velocity should also be maintained through the wet well to avoid the deposition of solids there. To prevent scouring of the pumps and pipes by grit in raw sewage pumping, and to prevent excessive head losses and surge controls difficulties in all applications, the velocities should not exceed 2.5 m/s.

The pumps must be selected and located in relation to the wet well so that the net positive suction head available (NPSHA) during the most severe conditions of operation exceeds the net positive suction head required (NPSHR). This criterion prevents cavitation, the formation of gas bubbles in the fluid within the pump when the liquid pressure drops below the vapor pressure of the gas, which decreases efficiency and output and can severely damage the pump impeller.

The working volume (volume between pump on and pump off levels) in the wet well should be large enough to ensure that no pump operates less than five minutes at a time; this criterion is desirable to increase pump lifetime. The working volume should also be small enough so that the retention time of sewage in the wet well does not exceed 30 minutes; this criterion is desirable to avoid the development of septic conditions in the wet well. These criteria may be impossible to satisfy if the range of flows is large, and the latter one is moot in a sewer system carrying septic tank effluent.

A valve pit allowing the hydraulic isolation of the entire lift station should be located outside the wet well so that the lift station can be shut down in emergencies without entry into the wet well.

Design for Safety - At least three types of potentially lethal hazards in lift stations must considered: confined space hazards; explosion hazards; and electrical hazards.

Forced ventilation must be provided in any lift station large enough to be entered. The ventilation can be continuous or intermittent; in addition, the blowers should be on whenever anyone is in the station. Continuous ventilation of wet wells should provide at least 12 air changes per hour, and intermittent ventilation, at least 30 (GWMRB, 1978). Hatches should also lock in the open position to prevent accidental lock-ins.

Maintenance procedures should also be planned for safety. No one should ever enter a lift station alone. One person should always remain outside with radio or telephone contact with rescue personnel. No one should enter a lift station without checking the concentration of oxygen and toxic gases within, either with a permanent or portable gas monitor. Rescue personnel, and preferably maintenance personnel, should have self-contained breathing apparatuses (SCBA) for entry into potentially toxic or oxygen-deficient atmospheres. Persons entering the wet well should be on tethers attached to hoists so that they can be pulled out without endangering the would-be rescuers' lives.

To avoid explosions, electrical wiring and circuitry should be designed for intrinsic safety; that is, no failure should produce a discharge of enough energy to ignite explosive gases potentially present in the lift station. Other spark sources, such as arc welding, must also be avoided. Electrical panels should be installed in accordance with local and national codes.

Reliability - Pumps, controls, and electrical circuits can fail. Because lift stations are often in remote locations in the sewer system, they should be equipped with telemetry or an autodialing alarm system or both, so that maintenance personnel can respond quickly to malfunctions. Metal parts exposed to the corrosive atmosphere in a lift station should be corrosion-resistant, or they may frequently need to be painted or replaced. Each pump should have a run-hour meter and a cycle counter for the scheduling of O&M operations.

Environmental Impact - Lift stations produce waste streams in addition to the sewage which ultimately reaches a treatment plant or overflow discharge. These are gases vented to the atmosphere and cleanings from trash baskets and bar screens. Lift stations use energy, resulting in an indirect environmental impact, and their construction potentially impacts their immediate surroundings.

Energy consumption - Lift stations consume energy in both pumping and maintenance.

Installation and Maintenance Costs

Costs include site acquisition, construction, operation and maintenance, including energy costs. The construction cost is generally related to the flow capacity of the lift station. At a given capacity, there is little correlation between head and cost (Newton and Sanks, 1989).

Operation and maintenance costs vary considerably, partly because the policies of sewer authorities vary considerably. For small and very small lift stations, maintenance costs can be much more significant than energy costs, largely because of the travel, labor and overhead cost of frequent inspections. For larger stations, the life-cycle energy cost may be 10-25 percent of the construction cost, and the maintenance cost perhaps as much.

4.2.4 Preliminary Treatment Facilities

Description

The purpose of preliminary treatment is to remove large objects, such as rocks, logs, and cans, as well as grit, in order to prevent damage to subsequent treatment and process equipment. Objects normally removed by preliminary treatment steps can be extremely harmful to pumps, and can increase downtime due to pipe clogging and clarifier scraper mechanism failures. Preliminary treatment usually consists of two separate and distinct unit operations: bar screening and grit removal.

There are two types of bar screens (or racks). The most commonly used and oldest technology consist of hand-cleaned bar racks. These are generally used in smaller treatment plants. The second type of bar screen is the type that is mechanically cleaned, which is commonly used in larger facilities. Grit is most commonly removed in chambers, which are capable of settling out high density solid materials, such as sand, gravel and cinders. There are two types of grit chambers:

- horizontal flow and
- aerated.

In both types the settleables collect at the bottom of the unit. The horizontal units are designed to maintain a relatively constant velocity by use of proportional weirs or flumes in order to prevent settling of organic solids, while simultaneously obtaining relatively complete removal of inorganic particles (grit).

The aerated type produces spiral action whereby the heavier particles remain at the bottom of the tank to be removed, while organic particles are maintained in suspension by rising air bubbles. One main advantage of aerated units is that the amount of air can be regulated to control the grit/organic solids separation, and less offensive odors are generated. The aeration process also facilitates cleaning of the grit. The grit removed from horizontal flow units usually needs additional cleaning steps prior to disposal.

Common Modifications - Many plants also use comminutors. These are mechanical devices that cut up the material normally removed in the screening process. Therefore, these solids remain in the wastewater to be removed in downstream unit operations, rather than being removed immediately from the wastewater.

In recent years, the use of static or rotating wedge-wire screens has increased to remove large organic particulates just prior to degritting. These units have been found to be superior to comminutors in that they remove the material immediately from the waste instead of creating additional loads downstream. Other grit chamber designs are available including swirl concentrators and square tanks.

Technology Status - Preliminary treatment has been widely used since the early days of municipal wastewater treatment. Wedge-wire screens are a newer technology.

Applications - Should be used at all municipal wastewater treatment plants, and also are normally used prior to wastewater pumping stations.

Limitations - None for normal municipal wastes.

Performance - Large screens are designed to remove all large debris, such as stones, wood, cans, etc. Grit chambers are designed to remove virtually all inorganic particles, such as sand and gravel. Wedge-wire screens remove up to 25 percent of TSS and associated BOD, and possibly reduce digester scum.

Residuals Generated - All unit operations will generate solids that will need disposal. Wedge-wire screens remove up to 0.2 m^3 of 12 to 15 percent solids (dry basis) for every 1,000 m^3/day of sewage. The grit and other solids are often land filled.

Design Considerations

Design Criteria - Bar Screens: Bar size, 5 to 20 mm width by 25 to 75 mm depth in spacing, 20 to 75 mm; slope from vertical, 0 to 45° ; velocity, 0.5 to 0.9 m/s. Grit Chambers: Horizontal velocities of 0.15 to 0.4 m/s, sufficiently long to settle lightest and smallest (usually 0.2 mm) grit particles with an additional factor of safety (up to 50 percent). Weir crests are generally set 100 to 300 mm above bottom.

Unit Process Reliability - Preliminary treatment systems are extremely reliable and, in fact, are designed to improve the reliability of downstream treatment systems.

Environmental Impact - Requires relatively little use of land. Requires minimal amounts of energy. Solids requiring disposal will be generated. Odors are common when removed grit contains excess organic solids and is not disposed of within a short time after removal.

Installation and Maintenance Costs

Costs include site acquisition, construction, operation and maintenance, including energy and solids disposal costs. The construction cost is generally related to the flow capacity of the pretreatment unit.

4.3 CENTRALIZED TREATMENT SYSTEMS AND DISPOSAL

4.3.1 Centralized Treatment Systems

Description

The four processes most commonly used to provide biological oxidation (secondary treatment) to organic material in wastewater are conventional activated sludge, extended aeration process, trickling filters, and stabilization ponds. In combination with physical processes for removal of suspended solids, the activated sludge process can consistently remove about 90 to 95 percent of the BOD and suspended solids contained in the raw wastewater. Trickling filters can remove about 80 to 90 percent of the same materials, and stabilization ponds about 90 to 95 percent. In addition, there are several combinations of these processes that can provide cost-effective solutions for specific applications. For instance, the Biolac process developed in Europe in the mid- 1970s is a combination of the concepts of the extended aeration activated sludge process and stabilization ponds. These processes are discussed in the following paragraphs and summarized in **Table 4-2**. Schematic diagrams of the principal components of each of these processes are included on **Figure 4-2**.

Conventional Activated Sludge Process - The Conventional Activated Sludge Process is usually used in larger municipal sewage treatment plants (more than 50,000 m^3/day) and consists of primary treatment followed by aeration, final sedimentation, and disinfection. In this type of process, air is bubbled through the wastewater and biomass mixture (mixed liquor) in aeration tanks. The air provides mixing and oxygen for micro-organisms.

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Extended Aeration Process - The extended aeration process is a variation of the activated sludge process often used for small communities. This provides a considerable reduction in the amount of sludge solids produced. While some attempts have been made to operate extended aeration plants without separate sludge wasting facilities, this usually has resulted in excess solids carryover in the effluent; thus, solids handling facilities are needed. The well-stabilized sludge which is produced is often put directly on drying beds without prior treatment. Primary sedimentation is usually omitted from the process to simplify sludge treatment and disposal. As with extended aeration plants, aerated lagoons are often favored for small communities because of their simplicity and ease of operation.

Extended aeration plants do have an advantage over the other two types where future plant expansion is anticipated. They are easily converted to the conventional activated sludge process, which generally provides more economical treatment at higher flow rates. Another common treatment system for small communities is the packaged extended aeration activated sludge plants. These prefabricated treatment units can be assembled in place in an area where construction materials and skilled labor are not readily available or cost-effective.

Trickling Filters - Trickling Filters comprise towers packed with stone, plastic, or redwood media. The biomass resides on the media. Wastewater is pumped to the top of the tower. As the wastewater flows down through the tower and over the media surfaces, it comes in contact with the biomass. The configuration of the media allows air to pass through the tower and supply oxygen to the biomass. To ensure continuous wetting of the biomass on the media, a portion of the effluent is recirculated to the biotower influent.

TABLE 4-2 COMPARISON OF ALTERNATIVE SEWAGE TREATMENT PROCESSES

Process	Typical Capacity Range m^3/day	Typical Range of BOD_5 & TSS Removal Efficiency, %	Typical Range of Effluent Quality, mg/l of BOD_5 & TSS	Typical Range of Capital Cost USD $/m^3$ Capacity*	Range of O&M Cost, ($/$m^3$) Treated	Sludge Management	Comments
Conventional Activated Sludge	>20,000	90 to 95	10 to 30	$200 to $700	$0.04 to $0.80	Generates primary and secondary sludge at a rate of 0.4 to 0.6 Kg per Kg of BOD5 removed.	More applicable for population centers of over 200,000 people. More cost-effective in areas of scarce land availability or of high cost of land.
Extended Aeration Activated Sludge Process	1,000 to 70,000	85 to 95	10 to 30	$150 to $500	$0.06 to $0.50	Generates secondary sludge at a rate of 0.15 to 0.3 Kg per Kg of BOD5 removed.	Applicable for communities of 200,000 or less. Area requirement about the same as conventional activated sludge.
Trickling Filters	3,000 to 80,000	80 to 85	15 to 40	$160 to $750	$0.03 to $0.40)	Generates primary and secondary sludge at a rate of 0.3 to 0.5 Kg per Kg of BOD5 removed.	Generally requires less maintenance than activated sludge. Less area requirements.
Stabilization Ponds	50 to 75,000	85 to 95	10 to 30	$65 to $400	$0.005 to $0.07	Sludge is accumulated and degraded in the pond. Typical sludge dredging occurs every seven to ten years.	Very little maintenance required. Good in tropical and subtropical climates. Large area requirements compared to the activated sludge process.
Extended Aeration Lagoons/Oxi-dation Ditch	1,000 to 70,000	85 to 95	10 to 30	$100 to $500	$0.03 to $0.50	Generates sludge at a rate of 0.05 to 0.15 Kg per Kg of BOD5 removed.	Suitable for areas where land cost and availability is not a problem. Similar to stabilization ponds but requires mechanical equipment for aeration.
Package Extended Aeration Plants	50 to 5,500	85 to 95	10 to 30	$150 to $500	$0.10 to $0.80	Same as Extended Aeration.	Similar to extended aeration but process units are prefabricated of steel or pre-stressed concrete.

* Land cost is not included.

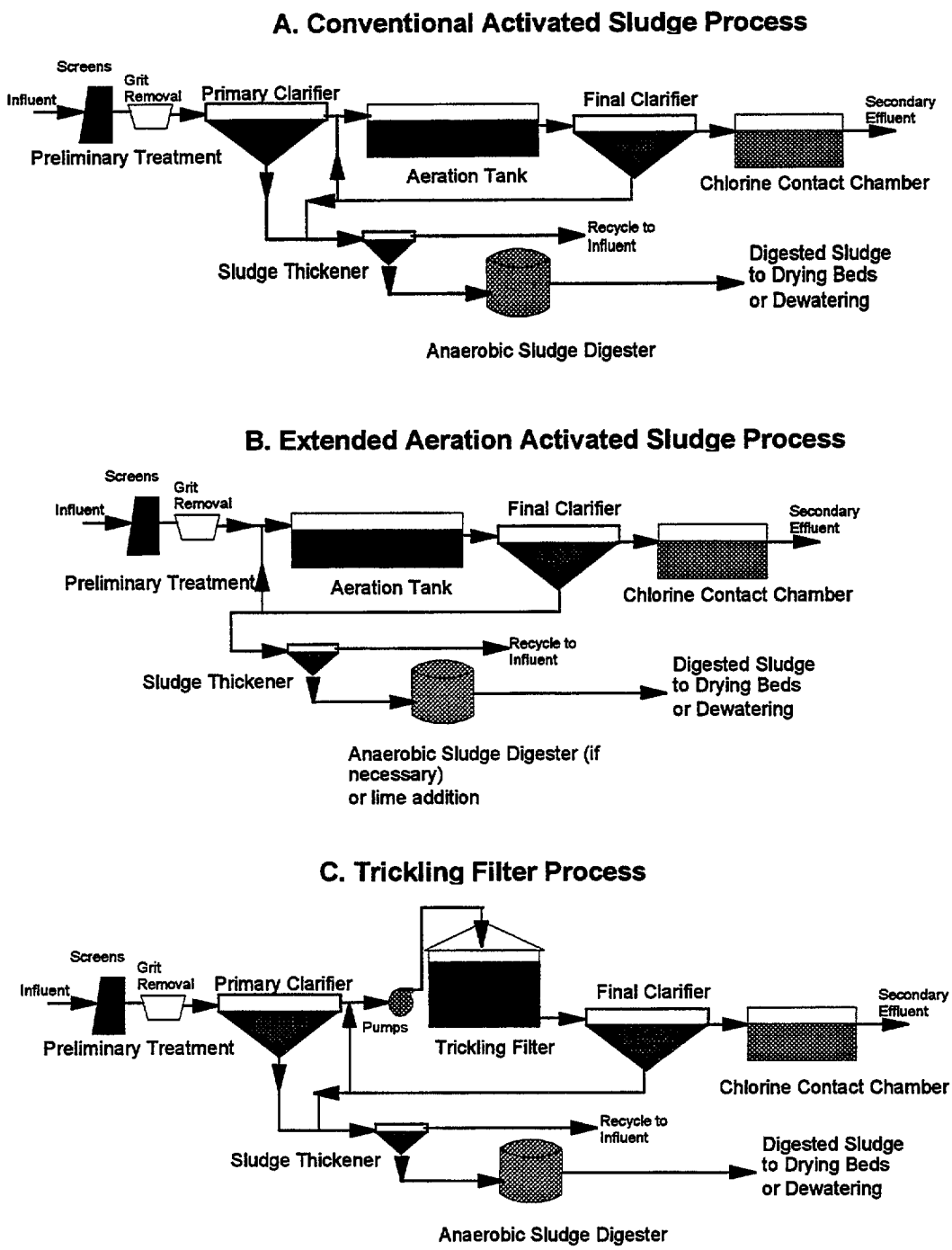

Figure 4-2 Secondary Treatment Processes

Stabilization Ponds - Stabilization pond treatment offers several advantages over more complex mechanical treatment plants. If properly designed and adequately operated, stabilization pond treatment systems offer a simple, reliable, and low maintenance means of achieving a high degree of wastewater treatment. Apart from the inherent simplicity of treatment of the liquid phase, adequate design of the sludge storage capacity virtually eliminates the problems of sludge disposal. Sludge produced in these systems is contained and degraded anaerobically (methane fermentation) within the stabilization pon ds themselves, requiring dislodging only after extended operating periods. There are several types of stabilization ponds, including:

Facultative Lagoons. Facultative lagoons are partially aerobic and partially anaerobic. Photosynthesis and surface reaeration provide oxygen for aerobic stabilization in upper layers. They favor algae growth along with the growth of aerobic, anaerobic, and facultative microorganisms. Such ponds are predominantly aerobic during daylight, as well as during some hours of the night. In the few remaining hours, the pond bottom waters may turn anaerobic. Benthic deposits are generally anaerobic beyond the first few millimeters from the sludge-water interface. Nitrogen removal depends on residence time, pH, and temperature in the pond. There is some phosphorus removal through uptake by algae.

Completely Mixed Aerated Lagoons/Oxidation Ditch. These are essentially extended aeration activated sludge systems, without settling basins or solids recycle. Solids in the pond are maintained in virtually complete suspension and pass out with the effluent. BOD_5 removals are relatively low due to the BOD_5 demand of the suspended organic solids, but soluble BOD_5 removals are typically greater than 85 percent, depending on the detention time. Typically, ammonia conversion to nitrates of approximately 50 percent has been reported for detention times of approximately 2.5 days. Total nitrogen removal, however, is low due to the absence of denitrification.

Design Considerations

The most distinctive design considerations for secondary treatment systems are summarized in **Table 4-3.**

TABLE 4-3 DESIGN CONSIDERATIONS OF ALTERNATIVE SEWAGE TREATMENT PROCESSES

Process	Typical Capacity Range, m^3/day	BOD_5 Loading	Detention time, days	Side Water Depth, m.	Sludge Production
Conventional Activated Sludge	>20,000	0.3 to 0.4, kg of BOD_5 per kg of MLVSS	.15 to 0.35	2.2 to 5	Generates primary and secondary sludge at a rate of 0.4 to 0.6 Kg per Kg of BOD5 removed.
Extended Aeration Activated Sludge Process	1,000 to 70,000	.05 to 0.15 kg of BOD_5 per kg of MLVSS	0.75 to 1.5	1.5 to 3	Generates secondary sludge at a rate of 0.15 to 0.3 Kg per Kg of BOD5 removed.
Trickling Filters	3,000 to 80,000	160- 880 kg BOD_5 per 1000 m^3 of media per day	.15 to .5	3 to 12	Generates primary and secondary sludge at a rate of 0.3 to 0.5 Kg per Kg of BOD5 removed.
Stabilization Ponds	50 to 75,000	22-67 kg BOD_5 per hectare per day	25-180	1 to 2.5	Sludge is accumulated and degraded in the pond. Typical sludge dredging occurs every seven to ten years.
Extended Aeration Lagoons/Oxi-dation Ditch	1,000 to 70,000	8-320 kg BOD_5 per 1000 m^3 per day	7 to 20	1.5 to 3	Generates sludge at a rate of 0.05 to 0.15 Kg per Kg of BOD5 removed.
Package Extended Aeration Plants	50 to 5,500	.05 to 0.15 kg of BOD_5 per kg of MLVSS	1 to 5	1 to 2.5	Same as Extended Aeration.

4.3.2 Disposal Systems for Centralized Treatment Systems

The applicable effluent disposal options for the study area include:

- Surface water discharge
- Constructed wetlands
- Natural wetlands

Surface Water Discharge - This effluent disposal option involves discharging the treated effluent to the receiving body of water. This requires an evaluation of the receiving stream characteristics to determine if the body of water has the assimilative capacity to receive the wastewater effluent. It is preferred to find a location nearby the treatment plant in order to reduce the effluent transport costs. Currently, there is very little water quality data available for the study area.

Constructed Wetlands - The constructed wetlands can be either designed for surface flow (SF), for subsurface flow (SSF), or for a combination of hydraulic modes.

Surface Flow (SF) Constructed Wetlands. Surface-flow constructed wetlands mimic natural wetlands in that water principally flows above the ground surface, as shallow sheetflow through a more or less dense growth of emergent wetland plants. Features common to all constructed SF wetland:

- an inlet device,
- the wetland basin,
- the wetland plants, and
- an outlet device.

Various configurations exist for each of these features. The inlet device initiates the flow of wastewater into the constructed wetland. Constructed wetland inlet devices are designed to initiate and maximize sheetflow of wastewater into the wetland cell.

The design of the constructed wetland, including size, number, and shape depend on the site specific conditions and are important for proper system use. Basin size should take in consideration the reaction kinetics and requirements for compliance with regulatory limits. The number of basins is determined by flow rate, land area constraints, and operational redundancy requirements. The shape of the basins will be dictated by site specific conditions and designer preference.

The SF constructed wetland outlet device recollects surface water from the cell and directs this flow to downstream wetland cells or to the ultimate receiving

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water system. Outlet devices in SF constructed wetlands frequently are designed to provide water level and flow control as well as the ability to measure outflow rates.

Constructed Subsurface Flow (SSF) Wetlands. Constructed SSF wetland system treat wastewater by passing it horizontally or vertically through a permeable media planted with wetland plants. Microbial attachment sites are located on the surface of the media and on the roots of the wetland plants. Although SSF wetlands have many features in common with SF wetlands, they also have a number of differences that are important during project planning. The principal components of a constructed SSF wetland are the inlet distribution system, the basin configuration, the bed media, the plants, and the outlet control system. The inlet wastewater distribution systems and basin configuration in SSF constructed wetlands have the same function as in SF wetlands, but they are designed in a fundamentally different fashion. To operate correctly, a SSF system must initiate and maintain all or most flow, subsurface and horizontally, through a permeable media. The principal design considerations for a SSF system are the media cost and permeability and, for a given permeability, the cross-sectional area necessary to initiate flows into the inlet zone.

Plant selection is frequently quite similar for SF and SSF constructed wetlands. The same small group of emergent wetland plants grow best in both systems. Outlet devices have the same functions in SSF as in SF constructed wetlands. The principal difference between the two is that SSF outlets must be able to collect water from the base of the media, typically between 0.3 to 0.6 m below the wetland bed (ground) surface.

Natural Wetlands - A significant fraction (about 15 percent) of the area has active marshlands, wetlands and waterways. This makes this disposal method an attractive disposal option. From an implementation standpoint, natural wetland treatment systems are simpler than constructed wetlands. The designer must collect and deliver the wastewater, but nature has provided the basin and vegetation. Nevertheless, natural wetland systems include the same components as constructed wetlands, and the basin and vegetation must be evaluated during planning to determine the suitability for project goals. A natural wetland treatment system include the inlet distribution system, the wetland basin, the natural wetland vegetation, the wetland sediments, and the outlet design features.

4.4 WASTEWATER FLOW REDUCTION

Wastewater flow reduction is another alternative to consider in planning wastewater treatment facilities for a small community. Flow reduction is not a solution to wastewater management, but it will allow a small community to use a smaller treatment facility and reduce the cost of wastewater treatment. Wastewater flow reduction can be achieved by conserving water and recycling or reusing treated wastewater. Both approaches will reduce the water used and reduce the wastewater generated.

There are several ways to conserve water and to recycle the wastewater. Water conservation can be achieved through the installation of water-saving devices, fixtures, and appliances, the application of alternative fixtures such as waterless toilets to treat human wastes, and the elimination of wasting water. Wastewater recycle and reuse can be done by collecting and treating the entire wastewater volume or a fraction for subsequent reuse in certain activities. Using treated bath or laundry wash water for toilet flushing is the most applicable method for recycling and reusing wastewater.

4.4.1 Toilet Flushing

Toilet flushing water accounts for approximately 30 to 40 percent of household water usage. Each flush of a conventional toilet uses between 15 to 25 liters (4 and 7 gallons) of water and averages 20 liters (5.3 gallons). To reduce the amount of toilet flushing water, toilet inserts, dual flush toilets and water-saving toilets can be used to replace the conventional toilet. The flow reduction control devices are described as follows:

Toilet Inserts - Plastic bottles, flexible panels, drums or plastic bags are all suitable low-cost toilet inserts. These inserts are easy to use and can be installed by the homeowner without any modifications to the conventional toilet. This study reveals great potential for using toilet inserts. A pair of 1 liter plastic bottles saves approximately 10 percent of the water used in flushing a conventional toilet. However, there is a limitation on the number of inserts that can be used at any one particular toilet as an excessive reduction in flushing water might result in the need of double flushing the unit to carry solid wastes. Periodic inspections are necessary to assure the proper installation of inserts.

Dual Flush Toilets - This type of toilet enables the user to select different cycles for flushing, a short flush for liquids and a normal flush for solids. The liquid waste cycle usually uses 9.5 liters (2.5 gallons) per flush.

Water-Saving Toilets - The water-saving toilets have a smaller water tank. These toilets use only 13 liters (3.5 gallons) per flush as compared to 20 liters (5.3 gallons) for a conventional toilet. In most cases, the flushing rim and priming jet are redesigned to initiate siphon flush in a smaller trapway with less water. Total flow reduction varies from 4 to 15 percent.

4.4.2 Water Use Habits

Inadequate water use habits will waste a large amount of water and generate more wastewater. These wasteful water use habits include flushing the toilet to dispose of a cigarette butt, running water while brushing teeth or shaving, taking a longer than necessary or unnecessary shower, washing clothes with a partial load or with setting on inappropriate cycle. Water saving and wastewater flow reduction by eliminating these bad habits may vary but it is an effective way to save water.

Clothes Washing - Mechanical clothes washers consume water from 50 to 200 liters (13 to 53 gallons) per usage depending on the model and manufacturer of the washing machine and the cycle selected. It is the second largest activity in a household contributing to daily water use and wastewater flow. It is estimated, that in homes that have mechanical clothes washers, approximately 22 percent of the water is used for clothes washing. However, this percentage is expected to be less in the study area, where many homeowners do not have these type of appliances. However, it is possible that in the next decade, the amount of households with mechanical clothes washers will increase significantly (as more affluent people move to the area). Wastewater reduction can be achieved by adequate cycle settings for different loadings. Frontloading model washers can also reduce water consumption up to 40% for a comparable load of clothes in a top-loading model. Another method of saving water is to reuse rinse water. Rinse water can be stored in a nearby laundry sink or a container for subsequent use as the wash water for the next load by setting an optional cycle.

Bathing - A typical value in the quantity of wastewater generated by a bath or shower is estimated at about 10 to 40 liters (2.6 to 10.6 gallons) per capita per day. The water usage by this activity comprises approximately 30 percent of the total household water consumption. Several flow reduction devices are available for showering activity. In recognizing that the study area consists of different pressure zones of water supply, these devices are only applicable for those houses located in the lower elevations with a high water pressure. Shower flow control devices such as inserts and restrictors to reduce flow rate by reducing the diameter of water supply lines and reduced-flow showerheads usually consume 5.7 to 11.4 liters (1.5 to 3.0 gallons) of water per minute instead of 11.4 to 30 liters (3 to 8 gallons) per minute by conventional showerheads.

4.4.3 Miscellaneous Methods

Other wastewater flow reduction methods are: (1) elimination of water leaks, (2) maintaining adequate water pressure, (3) restrictions on faucet flow, and (4) wastewater recycle and reuse.

Elimination of Water Leaks - Water leaks from plumbing systems and household fixtures can waste large amounts of water. Leaking toilets, dripping faucets and showerheads are common water leaks. With proper maintenance of water supply systems and fixtures, these water leaks can be eliminated.

Maintaining Adequate Water Pressure - Water flow rates through faucets, showerheads and other fixtures are highly dependent on the water pressure. For most residential areas, a pressure of 40 psi is adequate. Pressure in excess of this value will result in unnecessary water use. Therefore, pressure reducing valves can be installed in houses with higher water pressure to reduce the flow rate and conserve water.

Restrictions on Faucet Flow - For those high pressure areas, restrictors, aerators or inserts can be installed on water faucets to reduce water flow if pressure reducing valves cannot be installed in the water supply system. These devices usually limit flow to 11.4 liters (3 gallons) per minute and reduce water usage 4 to 8 liters (1 to 2 gallons) per capita per day.

Wastewater Recycle and Reuse - To simplify the treatment process, and performance requirements, only wash water from bath and laundry are treated and reused for toilet flushing. These wastewaters can be collected and stored for subsequent filtration and disinfection. However, the recycle and reuse system requires separate water supply and drainlines. The cost in modifying the system with a treatment process is one to two orders of magnitude greater than the cost for flow reduction devices. Costs as well as public acceptance are critical factors in considering this alternative.

SECTION 5. EVALUATION OF SHORT-TERM ALTERNATIVES FOR THE KOTTE URBAN COUNCIL AREA

This section covers the short-term wastewater management alternatives for the Kotte Urban Council area to the year 2002.

5.1 BASIS FOR PROJECT EVALUATION

Project evaluation requires comparing the costs, environmental consequences, effectiveness, reliability, flexibility, implementability, and regional and islandwide compatibility of the project alternative plans. The following paragraphs present the bases for these comparisons.

Present Worth. The present worth of each alternative provides the basis for cost comparison. Present worth is the sum of money which, if invested now at a given rate, would provide exactly the funds required to make all future payments. Present worth takes into account all capital costs, operation and maintenance costs, and salvage values during the 20-year planning period. The present worth calculation presented in this report uses the interest rate of 10 percent. The salvage value is assumed to be zero in all cases.

Environmental Factors. A significant part of the planning process involves addressing the environmental factors for the alternative projects. This analysis is generally conducted separately from the engineering portion of the facilities plan and is titled the Environmental Impact of the Selected Alternatives.

Other Significant Factors. Several factors other than cost and environmental considerations must be examined during this project's cost-effectiveness analysis. The alternative with the apparent least cost is not always the best suited to meet the study area's needs. Project effectiveness, reliability, and flexibility must also be considered because a project is only as sound as its weakest link. If the system cannot function effectively and reliably, the cost is of little importance since the project will not be selected or will require premature replacement. Consideration must also be given to project implementation and its compatibility with regional and islandwide planning. These issues are important when considering time constraints and long-range community goals.

> Effectiveness. Project effectiveness is basically measured in terms of one goal: to eliminate existing health hazard conditions in the study area. The project must eliminate the unsanitary conditions and prevent them from recurring or occurring elsewhere. The degree to which each alternative can accomplish this goal must be considered.
>
> Reliability. Reliability can be expressed as the degree of assurance that the project will meet or exceed expectations and the likelihood that mechanical and process failures will occur infrequently with minimal consequences. It is related principally

to the complexity and sensitivity to breakdown of mechanical equipment and to the upset of treatment systems. Simplicity usually provides greater reliability; for example, collection systems depending solely on gravity flow are considered more reliable than mechanically and biologically complex treatment systems, such as activated sludge.

Flexibility. There is an obvious advantage to a public utility system which can be readily modified to meet changing conditions, such as changes in regulatory requirements or in an area's development characteristics. Generally, the most flexible system is the one that requires the least capital investment in major structures which represent irrevocable capital commitments, such as treatment plants. Flexibility also allows for system modification as developing technology permits a reduction in cost or an increase in project effectiveness.

Implementation. Since the "No Action" alternative has been eliminated from further evaluation, a project to alleviate potential health hazards in the study area must be implemented. Of course, the proper legal and administrative channels must be followed to undertake the job and to provide the necessary financial support. As a general rule, preferred scoring is given to projects characterized by: 1) which make the smoothest transition from the planning stage into construction and operation; 2) do not require the establishment of radically different administrative procedures; 3) have the fewest controversial features; and 4) do not require large new property acquisitions.

Compatibility with Regional and Islandwide Planning Documents. The smoothest transition from the planning stage to the design and construction stage will occur with the alternatives most compatible with regional planning goals.

5.2 SUMMARY OF PREFERRED TECHNOLOGIES

The preferred technologies that passed the preliminary screening and are selected for further evaluation include:

5.2.1 Individual On-site and Community Systems

This is a preferred technology for new construction in low density areas where collection systems and centralized treatment are not available or feasible in the short-term. Other technologies presented in Section 4 can be considered when the terrain's physical conditions are inadequate. A community system may be useful for a cluster of single family homes or multi-story buildings, office complexes, commercial areas, etc. The preferred systems for this type of application, include: a collection system, a septic tank, a leaching field, and a package treatment plant with surface discharge.

5.2.2 Areawide System

The areawide systems require a sewer collection system and a treatment and/or disposal system. The technologies to be considered for further evaluation include:

Trickling Filters
Trickling Filters Coupled with Wetlands
Conventional Activated Sludge
Extended Aeration Process
Facultative Lagoons
Primary Treatment and Pumping

5.3 INDIVIDUAL ON-SITE SYSTEMS

The principal construction parameters for single and multi-family septic tank systems are presented in **Table 5-1**. The estimated costs for properly designed single and multi-family septic tank systems are shown on **Figure 5-1**. Likewise, the operation and maintenance costs for septic tanks are presented on **Figure 5-2**.

Table 5-1 Principal Construction Parameters for Septic Tank Systems

Number of People Served	Flow M3/day	Tank Volume M3	Tank Volume Gallons	Length m	Dimensions Width m	Dimensions Depth m	Concrete Volume M^3	Reinforced Steel kg	Excavation M^3	Formworks M^2	Backfill M^3
5	0.9	1.06	279.0	1.45	0.73	1.00	2.56	127.9	1.3	8.4	0.40
10	1.7	1.82	481.0	1.91	0.95	1.00	3.43	171.4	2.3	11.7	0.68
15	2.6	2.60	688.2	2.28	1.14	1.00	4.17	208.4	3.3	14.7	0.98
25	4.3	4.22	1,116.1	2.91	1.45	1.00	5.45	272.7	5.3	20.3	1.58
50	8.5	8.49	2,244.1	4.12	2.06	1.00	8.13	406.6	10.6	33.5	3.19
100	17.0	17.39	4,595.0	5.28	2.64	1.25	12.43	621.3	21.7	52.6	6.52
200	34.0	33.92	8,961.7	6.73	3.36	1.50	18.57	928.5	42.4	81.7	12.72
400	68.0	74.88	19,782.5	8.65	4.33	2.00	30.25	1,512.4	93.6	134.5	28.08

Source : Unit Costs for Sri Lanka. (See ANNEX 2)

Assumes :	170	liter per capita per day
Cost of concrete =	$ 110.00	per m3
Cost of steel =	$ 0.80	per kg
Cost of Excavation =	$ 2.00	per m3
Cost of Backfill =	$ 1.50	per m3
Cost of formworks =	$ 20.00	per m2
Septic tank pumping & disposal =	$ 13.64	per pumping

FIGURE 5-1 Average New Construction Cost for Septic Tanks in the Kotte U.C. Area

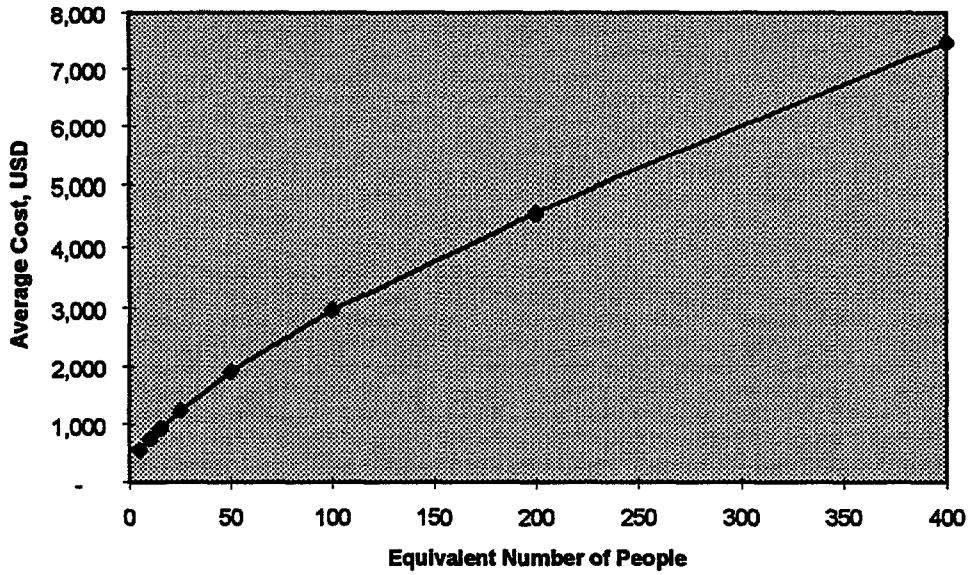
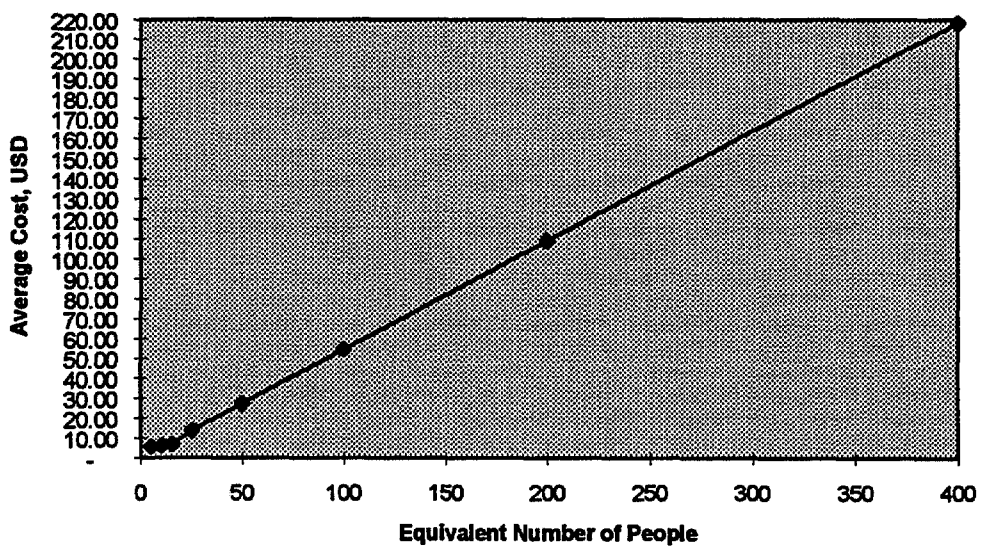


FIGURE 5- 2 Average Annual O&M Cost for Septic Tanks in the Kotte U.C. Area



The principal construction parameters for single and multi-family leaching field systems are presented in **Table 5- 2**. The estimated costs for properly designed single and multi-family leaching field systems (in areas with the best percolation rate of 4 minutes per centimeter or faster) are shown on **Figure 5-3**. The cost for areas with lower soil percolation rates (5.9 min/cm) is shown on **Figure 5-4**.

Table 5-2 Construction Parameters of Leaching Field Systems

Number of People Served	Flow M3/day	Leaching Field Area, m2	Number of Fields	Pipe No. 1 size mm	Pipe No. 2 size mm	Width of the field, m	Length of the field, m	Pipe No. 1 Quantity Lm	Pipe No. 2 Quantity Lm
5	0.9	4.17	1	100	100	1	4.17	4.17	6.00
10	1.7	8.35	2	100	100	3	2.78	8.35	8.00
15	2.6	2.52	2	100	100	3	4.17	2.52	8.00
25	4.3	20.87	3	100	100	5	4.17	20.87	10.00
50	8.5	41.75	4	150	150	9	4.64	41.75	14.00
100	17.0	83.50	5	150	150	11	7.59	83.50	16.00
200	34.0	166.99	5	200	200	12	13.92	166.99	17.00
400	68.0	333.98	5	200	200	15	22.27	333.98	20.00

Source : Unit Costs for Sri Lanka. (See ANNEX 1)

Percolation Rate =	10	minutes/in.	3.94 min./cm
Maximum rate of sewage application =	5	Gal/ft^2/day	203.60 liters/m^2/day
Distance from the Septic tank to the leaching field =	19.67	feet	6.00 meters
Distance between leaching fields =	6.56	feet	2.00 meters

FIGURE 5-3 Average New Construction Cost for Leaching Fields With Soil Percolation Rates of 4 min/cm in the Kotte U.C. Area

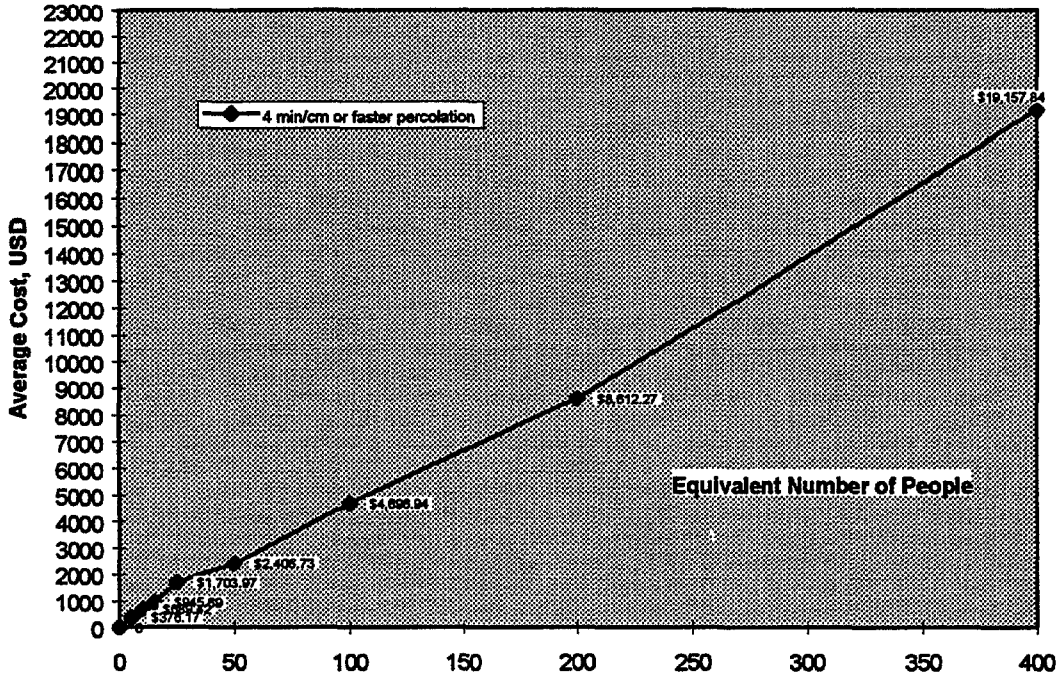


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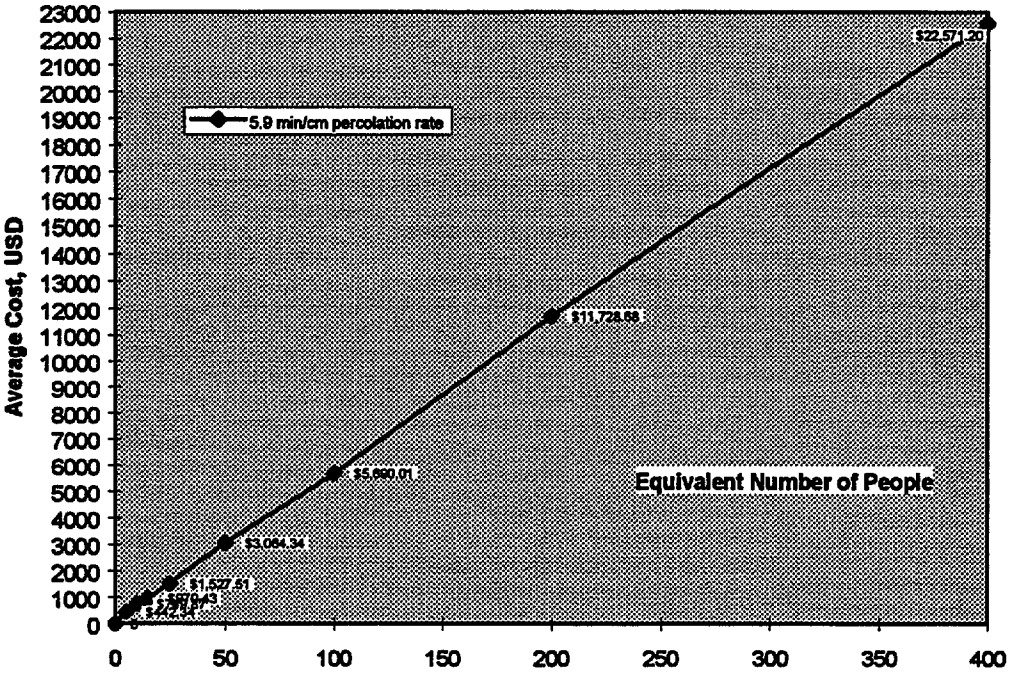
FIGURE 5-4 Average New Construction Cost for Leaching Fields With Soil Percolation Rates of 5.9 min/cm in the Kotte U.C. Area



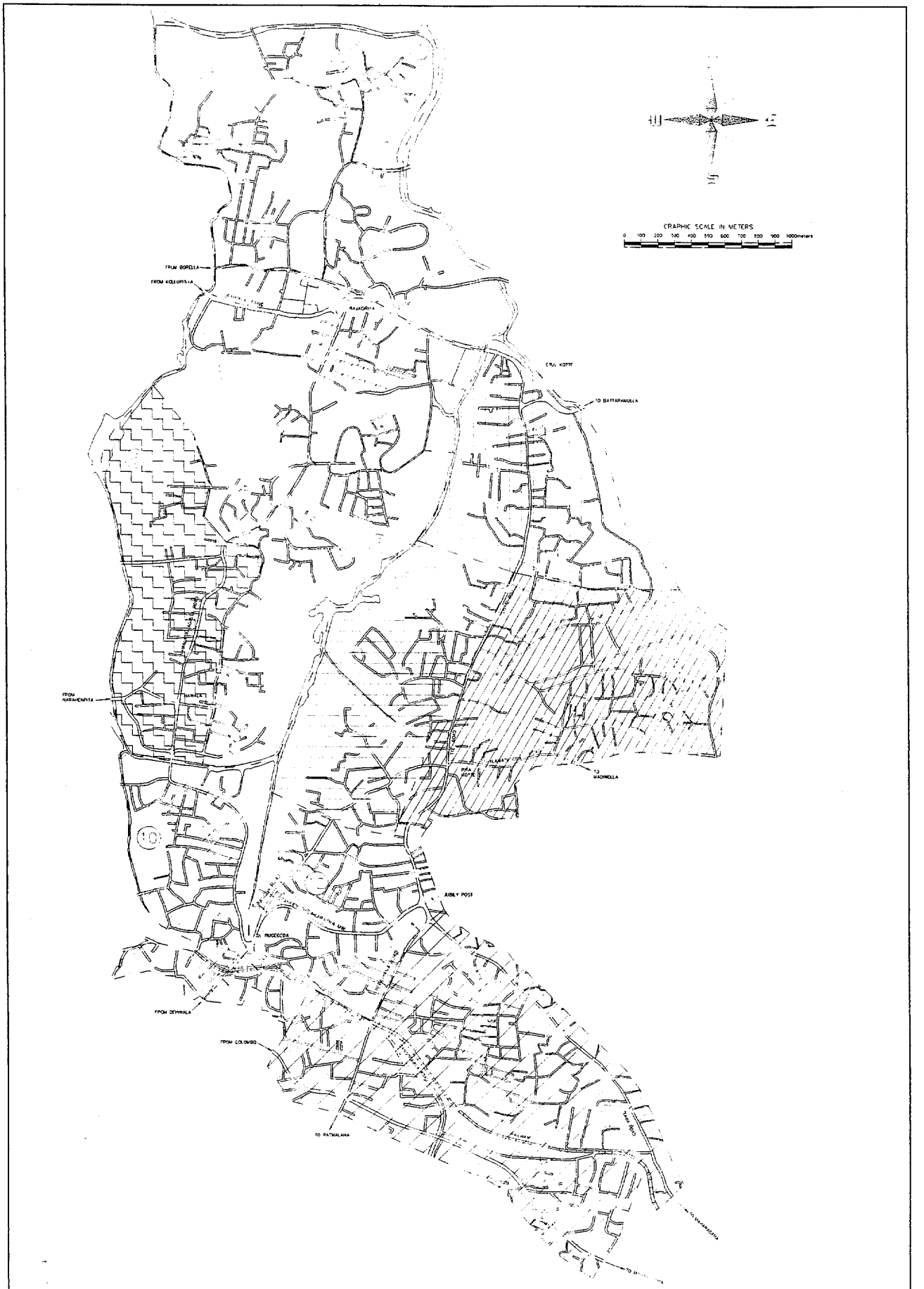
5.4 COMMUNITY-WIDE COLLECTION AND TREATMENT SYSTEM FOR THE KOTTE URBAN COUNCIL AREA

5.4.1 Collection System

All community treatment systems require sewage collection. For this study, the study area has been divided into 12 drainage basins that drain to a main pumping station. The drainage basins are shown on **Figure 5-5**. The preliminary design of the sewer system is presented on **Figure 5-6**. A larger map of the same preliminary design is presented in Annex 4. Due to the topography (characterized by rolling terrain ranging from 2 to 80 meters above mean sea level) of the study area, the sewage collection system required several lift stations in order to avoid construction of deep sewers.

The sewer collection system must be designed for the future conditions peak daily flows. It is estimated that the Kotte U.C. area will generate by the year 2010 an estimated average daily wastewater flow of about 35,570 m^3 per day. The peak hourly flow from the area is estimated at about 4,200 m^3 per hour.

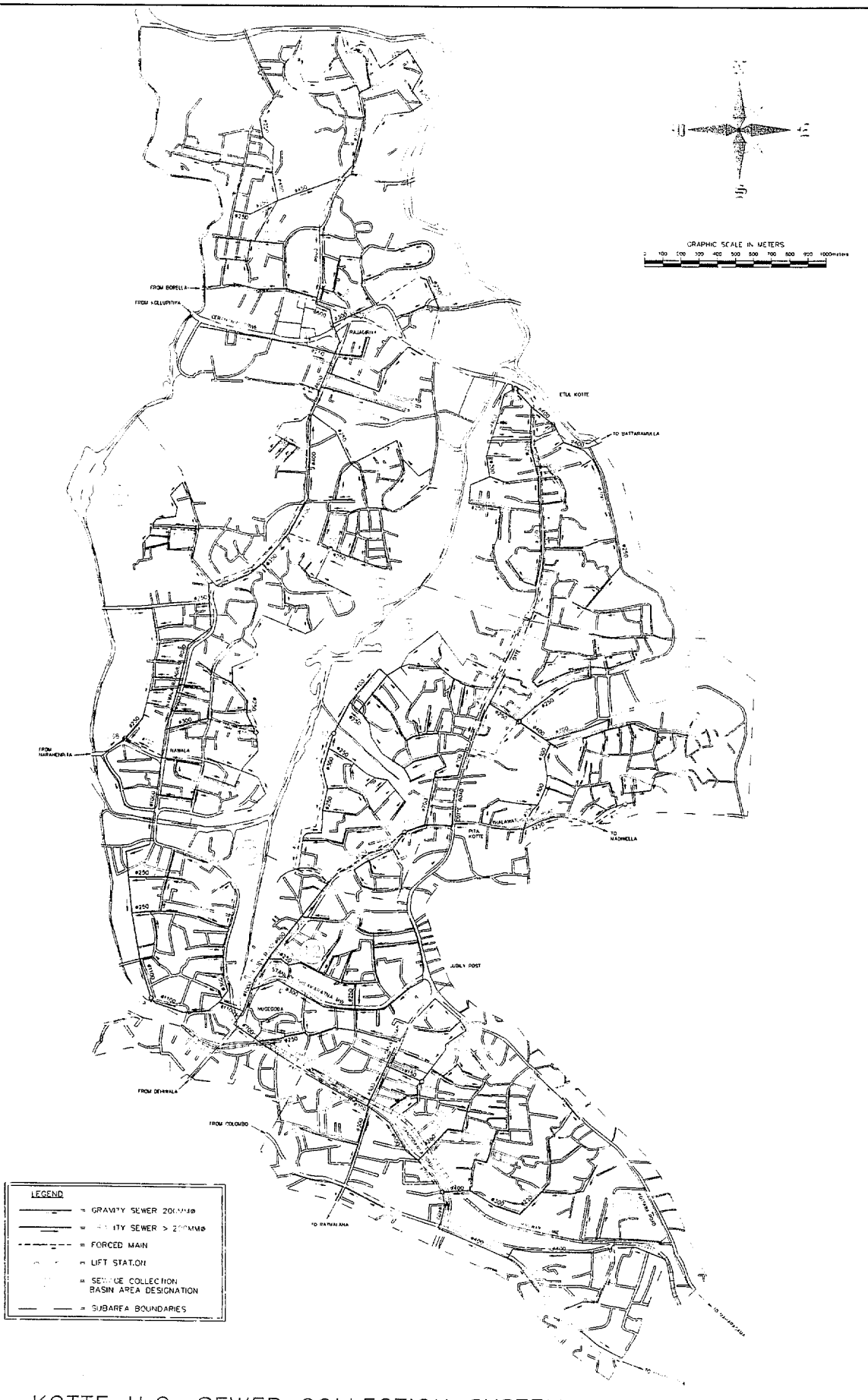
BEST AVAILABLE



SEWAGE DRAINAGE AREAS FOR KOTTE U.C.

FIGURE 5-5

BEST AVAILABLE



KOTTE U.C. SEWER COLLECTION SYSTEM

FIGURE 5-6

A preliminary estimate of sizes and length of sewer pipes is summarized on **Table 5-3** and presented in more detail in Annex 2. It is estimated that the sewer project will need about 800 manholes.

Table 5-3
Summary of Sewer Pipes

Pipe Diameter, mm	Total length of pipe, linear meters
200	47,600
250	560
300	5,250
400	3,960
450	500
600	1,500
700	800
900	1,450
1,000	2,170
1,100	650
Total	73,470

The material to be used for sewer construction is PVC pipe. The manholes will be made of cast-in-place concrete.

The twelve drainage basins of the Kotte U.C. require 17 lift stations. The preliminary design parameters of the lift stations is summarized in **Table 5-4**. All the lift stations will use submersible pumps in sets of 2, 3 or 4 pumps. All stations will have one spare pump and the rest will be duty pumps to meet the peak hourly demand.

The lift stations will discharge raw sewage via a force main to another manhole at a higher elevation. The pipe material used in all the force mains is ductile iron. The summary of force main pipe requirements are summarized in **Table 5-5.**

Table 5-4
Summary of Design Characteristics of the Proposed Lift Stations

Lift Station No.	No. of Pumps	Ave. Daily Flow, L/s	Peak Hourly Flow, L/s	Pump Motor, KW	Total Head, Dynamic meters	
					Average	Maximum
1	2	4.8	18.0	3.7	33.5	44.1
2	3	56.2	157.0	5.6	11.9	16.9
3	2	12.8	44.0	3.7	15.1	26.5
4	3	131.0	318.0	37.3	33.6	53.1
5	2	11.5	40.0	3.7	22.2	29.9
6	2	10.9	42.0	3.7	23.7	33.3
7	2	11..5	44.0	3.7	24.1	32.9
8	3	27.1	92.0	3.7	19.0	22.0
9	3	53.3	165.0	3.73	63.7	93.4
10	2	6.7	27.0	1.9	19.7	31.8
11	3	42.0	135.0	11.2	37.6	40.8
12	3	28.3	96.0	7.5	25.2	38.0
13	3	126.5	339	11.2	12.8	16.2
14	2	10.0	38.0	1.9	8.0	8.1
15	4	87.0	248.0	11.2	21.2	22.7
16	2	15.3	56.0	4.9	18.5	22.9
17	4	110.0	301.0	11.2	17.6	19.5

Table 5-5
Summary of Force Main Requirements

Pipe Diameter	Length of Pipe, Lm
100	500
125	1,650
150	300
200	1,500
250	3,350
350	2,000
400	150

The estimated present worth costs of the Kotte U.C. sewer system are summarized below. Likewise, the average annual cost for the Kotte U.C. sewer system is also included.

PRESENT WORTH COSTS

Discount Rate = 10.00%

Present Worth	MRs	USD
Present Worth Construction Cost	487	8,120,936
Present Worth O&M Cost	117	1,947,704
Total Present Worth	604	10,068,640

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AVERAGE ANNUAL COSTS

Item	Annual Cost
Amortization of Capital Cost *	$ 953,882
Average annual O&M cost	$ 228,389
Average annual cost	$1,182,272
Total average unit cost, $/m^3	$ 0.100
Total average unit cost, Rs/m^3	Rs 6.02

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years
Rate = 10.00 percent

5.4.2 Treatment Systems

The alternatives for wastewater systems for the Kotte Urban Council area have been developed using the following parameters:

DESIGN PARAMETERS

Average daily flow	26,400 M^3/day	6.97 MGD	4,844 GPM
Peak daily flow	33,000 M^3/day	8.72 MGD	6,055 GPM
Peak hourly flow	36,960 M^3/day	9.76 MGD	6,781 GPM
Peak/average flow ratio	1.25		
Peak hourly/average flow ratio	1.40		
Biochemical Oxygen Demand (BOD5)	5,271 kg/day	11,596 lb/day	
Biochemical Oxygen Demand (BOD5)	199 MG/L		
Total suspended solids (TSS)	5,272 kg/day	11,598 lb/day	
Total suspended solids (TSS)	199 MG/L		
Design Population	155,300		

<u>Alternative 1 - Trickling Filters</u>

This alternative is designed for an average capacity of 26,400 m^3 per day. The plant occupies an approximate area of 1.65 ha. Based on local conditions, it is necessary to pump the influent. This alternative provides the following components in the treatment process:

1) Liquid Stream

- Pre-treatment with Parshall flume, ultrasonic electronic flow meter, mechanical and manual bar screens, a mechanical grit chamber with grit washers and classifiers and a grit storage tank;

- Two circular primary clarifiers with mechanical sludge removers, primary sludge pumps, floating scum removers, and overflow weirs for the clarified effluent;
- One trickling filter unit with plastic media and recirculation;
- Two circular final clarifiers with mechanical sludge removers, sludge recirculation pumps, and effluent overflow weirs; and
- Chlorine contact chamber equipped with supply of chlorine gas to be used if necessary

2) Solids Management Stream

- Primary and secondary sludge thickener with mechanical flocculator, sludge sweeper, pumps for removal of concentrated sludge, and scum hoppers;
- An anaerobic digester with sludge mixer, thermal heat exchangers, steam boiler which uses methane gas, floating covers, and digested sludge pumps; and
- Sludge drying beds, with french drains and their pumping station.

3) Additional Facilities

Administration building with offices for operators, room for electronic controls and electromechanical equipment, sanitary sewers, wastewater laboratory, and chlorinators:

- Electrical sub-station with transformers and power supply;
- Paved roads;
- Water, electric and telephone service;
- Security fence;
- Painting of building exteriors; and
- Green areas, decorating improvements and gardens.

ANNEX 1 contains the design and cost estimating details of this alternative.

Cost: The construction cost of this alternative for wastewater treatment for Kotte is estimated at MRs 370.4 or $6.2 million USD. The summary of the construction,

operation and maintenance costs, and the present worth value of this alternative, are presented below:

PRESENT WORTH COST
Discount Rate = 10.00%

Present Worth	MRs,	USD
Present Worth Construction Cost	370	6,173,681
Present Worth O&M Cost	100	1,667,160
Total Present Worth	470	7,840,841

AVERAGE ANNUAL COSTS

Item	Annual Cost
Amortization of Capital Cost *	$725,158
Average annual O&M cost	$183,980
Average annual cost	$909,138
Total average unit cost, $/m^3	$0.077
Total average unit cost, Rs/m^3	4.63

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years
Rate = 10.00 percent

Reduction of public health and environmental risks. This alternative reduces the loads of organic and fecal matter into the surface waters and reduces public health risks. At the moment, the domestic wastewaters are discharged via subsurface onsite systems in most areas. The remaining wastewater is discharged directly to the ground surface or into nearby water bodies.

Reliability level. The trickling filter process is one of the oldest biological treatment processes and is one of the most reliable processes for cleaning the municipal wastewaters. The process operates satisfactorily in the project area's climate. This process removes more than 85 percent of the organic load, solids and fecal material. If chlorination is used from the effluent, the process removes more than 99.99 of the fecal coliforms. The primary and secondary sludge is treated completely and can be used as a soil supplement and fertilizer. The effluent can be re-used in the irrigation of high stalk plants and nonfood crops.

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Alternative 2 - Trickling Filter with Wetlands

This alternative is similar to the trickling filter alternative with the exception that it does not have the secondary clarifiers and instead, the effluent is discharged from the trickling filter into natural wetlands for further sedimentation and treatment. The plant area occupies an approximate area of 1.4 ha.. The minimum natural wetland area required is 3 ha. Treated effluent can be piped and allocated in different points of the natural wetland. Based on local conditions, it is necessary to pump the influent. ANNEX 1 contains the design and cost estimating details of this alternative.

Cost: The construction cost of the extended aeration alternative for wastewater treatment for Kotte is estimated at MRs 372 or $6.19 million USD. The summary of the construction, operation and maintenance costs, and the present worth value of this alternative, are presented below.

PRESENT WORTH COST

Discount Rate = 10.00%

Present Worth	MRs	USD
Present Worth Construction Cost	372	6,191,715
Present Worth O&M Cost	98	1,627,687
Total Present Worth	469	7,819,402

AVERAGE ANNUAL COST

Cost Item	Annual cost
Amortization of Capital Cost *	$727,277
Average annual O&M cost	$188,985
Average annual cost	$916,261
Total average unit cost, $/m^3	$0.078
Total average unit cost, Rs/m^3	4.66

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years
Rate = 10.00 percent

Reduction of public health and environmental risks. This alternative is compatible with the natural conditions of the study area and makes a beneficial use of the natural wetlands as a polishing treatment of the secondary effluent. It reduces the loads of organic and fecal matter into the surface waters, and reduces the public health risks.

Reliability level. The trickling filter process is one of the oldest biological treatment processes and is one of the most reliable processes for cleaning the municipal wastewaters. The process operates satisfactorily in the project area's climate. This process removes more than 85 percent of the organic load, solids and fecal material. The primary sludge is treated completely and can be used as a soil supplement and fertilizer. The secondary effluent quality is enhanced in the wetland and further reduces the organic and solids loads.

Alternative 3 - Conventional Activated Sludge

This alternative is designed for an average capacity of 26,400 m^3 per day. The plant occupies an approximate area of 1.5 ha.. Based on local conditions, it is necessary to pump the influent. The retention period in the aeration tanks is 7 hours. This alternative provides the following components in the treatment process:

1) Liquid Stream

- Pre-treatment with Parshall flume, ultrasonic electronic flow meter, mechanical and manual bar screens, a mechanical grit chamber with grit washers and classifiers and a grit storage tank;
- Two circular primary clarifiers with mechanical sludge removers, primary sludge pumps, floating scum removers, and overflow weirs for the clarified effluent;
- Four aeration tanks with diffused air supply;
- Two circular final clarifiers with mechanical sludge removers, sludge recirculation pumps, and effluent overflow weirs; and
- Chlorine contact chamber equipped with supply of chlorine gas to be used if necessary.

2) Solids Management Stream

- Primary and secondary sludge thickener with mechanical flocculator, sludge sweeper, pumps for removal of concentrated sludge, and scum hoppers;
- An anaerobic digester with sludge mixer, thermal heat exchangers, steam boiler which uses methane gas, floating covers, and digested sludge pumps; and
- Sludge drying beds, with french drains and their pumping station.

3) Additional Facilities

Administration building with offices for operators, room for electronic controls and electromechanical equipment, sanitary sewers, wastewater laboratory, and chlorinators:

- Electrical sub-station with transformers and power supply;
- Paved roads;
- Water, electric and telephone service;
- Security fence;
- Painting of building exteriors; and
- Green areas, decorating improvements and gardens.

ANNEX 1 contains the design and cost estimating details of this alternative.

Cost: The construction cost of this alternative for wastewater treatment for Kotte is estimated at MRs 387.6 or $6.46 million USD. The summary of the construction, operation and maintenance costs, and the present worth value of this alternative, are presented below.

PRESENT WORTH COST

Discount Rate = 10 %

Present Worth	MRs	USD
Present Worth Construction Cost	388	6,459,408
Present Worth O&M Cost	232	3,860,450
Total Present Worth	619	10,319,858

AVERAGE COST OF TREATMENT

Item	Annual cost
Amortization of Capital Cost *	$ 758,720
Average annual O&M cost	$ 479,429
Average annual cost	$1,238,144
Total average unit cost, $/m^3	$0.105
Total average unit cost, Rs/m^3	6.30

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years

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Rate = 10.00 percent

Reduction of public health and environmental risks. At the moment, the domestic wastewaters are discharged via subsurface onsite systems in most areas. The remaining wastewater is discharged directly to the ground surface or into nearby water bodies. This alternative reduces the loads of organic and fecal matter into the surface waters and reduces public health risks.

Reliability level. The conventional activated sludge process has been used for several years and is one of the most reliable processes for cleaning the municipal wastewaters. The process operates satisfactorily in the project area's climate. This process removes more than 90 percent of the organic load, solids and fecal material. If chlorination is used from the effluent, the process removes more than 99.99 of the fecal coliforms. The secondary sludge is treated completely and can be used as a soil supplement and fertilizer. The effluent can be re-used in the irrigation of high stalk plants and nonfood crops.
Operability. The system must operate without interruption for the design flow of sewage system for 24 hours a day, every day. The system requires training of operators and operation personnel. The process tolerates the mountain climate of the study area well.

Alternative 4 - Extended Aeration Process

This alternative is similar to the conventional activated sludge with the exception that it does not have primary clarifiers and the detention time in the aeration tank is 18 hours. The plant occupies an approximate area of 2.5 ha.. Based on local conditions, it is necessary to pump the influent. ANNEX 1 contains the design and cost estimating details of this alternative.

Cost: The construction cost of the extended aeration alternative for wastewater treatment for Kotte is estimated at MRs 367.1 or $6.67 million USD. The summary of the construction, operation and maintenance costs, and the present worth value of this alternative, are presented below.

PRESENT WORTH COSTS
Discount Rate = 10.00%

Present Worth	MRs	USD
Present Worth Construction Cost	367	6,674,494
Present Worth O&M Cost	207	3,763,171
Total Present Worth	574	10,437,665

AVERAGE ANNUAL COSTS

Item	Annual Cost
Amortization of Capital Cost *	$783,984
Average annual O&M cost	$461,442
Average annual cost	$1,245,426
Total average unit cost, $/m^3	$0.106
Total average unit cost, Rs/m^3	5.81

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years
Rate = 10.00 percent

Reduction of public health and environmental risks. This alternative reduces the loads of organic and fecal matter into the surface waters and reduces public health risks. At the moment, the domestic wastewaters are discharged via subsurface onsite systems in most areas. The remaining wastewater is discharged directly to the ground surface or into nearby water bodies.

Reliability level. The extended aeration process has been used for several years and is one of the most reliable processes for cleaning the municipal wastewaters. The process operates satisfactorily in the project area's climate. This process removes more than 90 percent of the organic load, solids and fecal material. If chlorination is used from the effluent, the process removes more than 99.99 of the fecal coliforms. The primary and secondary sludge is treated completely and can be used as a soil supplement and fertilizer. The effluent can be re-used in the irrigation of high stalk plants and nonfood crops.

Alternative 5 - Facultative Lagoons

In this alternative, like in the previous ones described, the municipal wastewaters are collected and transferred to the plant by means of gravitational sewage. The detention time of this process is about 34 days. The treatment system would consist of the following components:

- Flow meter using Cutthroat type flume
- Screens
- Grit chamber
- Facultative lagoons

The lagoons will require an area of 52 has. with three cells in series. The depth of each cell is 2.0 m. The effluent of the lagoons would empty into the natural wetlands. The effluent design concentration of the BOD5 is 30 mg/L.

Cost: The cost of this alternative is highly influenced by the price of the land in the Kotte U.C. area. The land costs range from Rs 30,000 to Rs 100,000 a Perch (one Perch = 272.25 sq. ft. or 25.3 sq. meters) or about $19.76 to $65.87 USD per sq. meter. The average value of land suitable for a lagoon system in the Kotte U.C. area would cost about Rs 50,000 a Perch or approximately $33.00 per sq. meter.

The construction cost of this alternative for wastewater treatment for the Kotte U.C. area is estimated at MRs 1,166.3 or 19.4 million USD of which about MRs 1.029 or $17.1 million USD are due to land cost. The summary of construction, operation and maintenance costs, and the present worth value of this alternative, are presented below. ANNEX 1 contains the details of the cost estimate.

PRESENT WORTH COST

Discount Rate = 10.00 %

Present Worth	MRs	USD
Present Worth Construction Cost	1,166.3	19,437,997
Present Worth O&M Cost	52	857,102
Total Present Worth	1,218.3	20,305,098

AVERAGE COST OF TREATMENT

Item	Annual Cost
Amortization of Capital Cost *	$2,283,180
Average annual O&M cost	$101,599
Average annual cost	$2,384,778
Total average unit cost, $/m^3	$0.202
Total average unit cost, Rs/m^3	12.14

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years
Rate = 10.00 percent

Reduction of public health and environmental risks. This alternative reduces the loads of organic and fecal matter into the surface waters, and reduces public health risks in a natural process without the use of energy or chemicals.

Reliability level. The facultative lagoon process is a low cost, low-tech alternative process that has been used for several years and is a very reliable process for cleaning the municipal wastewaters. It requires very little operation and maintenance. The process

operates very well in the project area's climate. This process removes more than 90 percent of the organic load, solids and fecal material. The process removes more than 99.99 of the fecal coliforms. The secondary effluent quality is enhanced in the wetland and further reduces the organic and solids loads.

5.5 REGIONAL COLLECTION SYSTEM AND DISCHARGE TO THE EXISTING SOUTHERN OUTFALL

This alternative involves building a collection system in the Kotte U.C. area, preliminary treatment (consisting of screening and grit removal), and a pumping station. The area required for the treatment plant is approximately 1 ha. The effluent is pumped to the junction box of the Wellawatta Pumping Station in Colombo to be discharged via the southern outfall into the ocean. This outfall is currently operating at half of its design capacity of 189,250 m^3 per day (50 MGD). The wastewater contribution from the Kotte area was included in the original outfall design. The distance from the pumping station in Kotte U.C. to the junction box is estimated at about 4 kilometers. A 900 mm diameter ductile iron pipe would be used.

1) Liquid Stream

- Pre-treatment with Parshall flume, ultrasonic electronic flow meter, mechanical and manual bar screens, a mechanical grit chamber with grit washers and classifiers and a grit storage tank, and a

- Pumping station.

2) Solids Management Stream

Dumpsters for screenings and grit collected in the preliminary treatment system are required.

3) Additional Facilities

Pump house building with offices for operators, room for electronic controls and electromechanical equipment, sanitary sewers, and wastewater laboratory.

- Electrical transformers and power supply;

- Paved roads;

- Water, electric and telephone service;

- Security fence;

- Painting of building exteriors; and
- Green areas, decorating improvements and gardens.

Cost: The construction cost of this alternative for wastewater treatment for the Kotte UC area is estimated at MRs 192 or $3.20 million USD. The summary of construction, operation and maintenance costs, and the present worth value of this alternative, are presented below. ANNEX 1 contains the design and cost estimating details of this alternative.

PRESENT WORTH COST

Discount Rate = 10.00%

Present Worth	MRs	USD
Present Worth Construction Cost	192	3,195,245
Present Worth O&M Cost	69	1,149,331
Total Present Worth	261	4,344,576

AVERAGE COST OF TREATMENT

Item	Annual Cost
Amortization of Capital Cost *	$375,312
Average annual O&M cost	$120,261
Average annual cost	$495,573
Total average unit cost, $/m^3	$0.042
Total average unit cost, Rs/m^3	2.52

* Notes: Average annual flow 11,787.302 m^3/yr.
Project financing = 20 years
Rate = 10.00 percent

Reduction of public health and environmental risks. This alternative reduces the loads of organic and fecal matter into the surface waters, and reduces the public health risks. Under this alternative, untreated effluent would be discharged to the marine environment. Currently raw sewage is being discharged through this outfall.

Reliability level. The system depends significantly on electrical power for pumping sewage, and, therefore, part of the system's reliability depends on the reliability of the power supply system. A stand-by generator can be provided but it increases the cost of the alternative significantly.

5.6 SUMMARY OF AREAWIDE ALTERNATIVES

The cost of the treatment alternatives evaluated are presented in the **Table 5-6**. As shown in this table, the preferred alternative from an economic standpoint is the use of preliminary treatment and ocean outfall disposal. In addition to the economic benefits, this is a good option because it has low maintenance requirements, very little mechanical components (influent pumping and headworks), and is a very reliable system. The major drawback of this option is that it requires electrical power.

Table 5-6 Summary of Areawide Alternatives

Alternative	Description	Capital Cost, UDS	Present Worth O&M Cost, USD	Total Present Worth Cost, USD	Capital Cost, MRs	Present Worth O&M Cost, MRs	Total Present Worth Cost, MRs
ALT. 1	Trickling Filter	6,173,681	1,667,160	7,840,841	370.42	100.03	470.45
ALT. 2	Trickling Filter with Wetlands	6,191,715	1,627,687	7,819,402	371.50	97.66	469.16
ALT. 3	Connventional Activated Sludge	6,459,408	3,860,450	10,319,858	387.56	231.63	619.19
ALT. 4	Extended Aeration	6,674,494	3,763,171	10,437,665	400.47	225.79	626.26
ALT. 5	Facultative Lagoons	19,437,997	867,102	20,305,098	1,166.28	52.03	1,218.31
ALT. 6	Preliminary Treatment Pumping and Outfall	3,195,245	1,149,331	4,344,576	191.71	68.96	260.67

The second best option from an economic standpoint is the trickling filter system coupled with natural wetlands for effluent polishing. The advantage of this process vs. pumping and outfall discharge is that the process treats the sewage to a higher level prior to discharge. However, the main drawback of the second best option is that it would require an additional area of about 2 ha. for the expansion of the wetlands to handle the year 2020 flows.

SECTION 6 - DESCRIPTION OF ALTERNATIVES FOR WASTEWATER AND EXCRETA MANAGEMENT BEYOND 2002 FOR THE KOTTE URBAN COUNCIL AREA

6.1 GENERAL

The alternatives for the management of wastewater and excreta beyond the year 2002 for the Kotte U.C. area must be compatible with the planning and implementation of such management systems prior to the year 2002. If an areawide system is implemented, then the resulting management strategy must be to utilize the existing infrastructure, to modify it, and expand it to meet future service requirements. If nothing is done or on-site (individual or community) systems are implemented instead of an areawide community system, then the use of a community system must be reassessed.

6.2 ON-SITE SYSTEMS

At the present time, there is not sufficient information to assess the existing conditions regarding the effectiveness of on-site systems in the study area. Therefore, it is not possible to determine if it can be considered as a feasible short-term or long-term solution for the study area.

The information needed to make this possible includes a complete community survey investigation regarding:

- Types of existing systems
- Problems associated with its operation, including: Public health, physical constraints, overflows, discharges to surface waters, etc.
- Demographics
- Socio-economic information
- Soil characteristics/adsorption capacity
- Seasonal water table elevation
- Willingness of public to pay for a sewer system and the connection to the system.

The survey must have statistical validity and represent a significant coverage of the study area.

6.3 AREAWIDE SYSTEMS

The areawide alternatives involve a collection system and a treatment system. Assuming that the initial project (before 2002) involved one of the areawide systems described in Section 5, then the alternative beyond 2002 would involve the expansion of the system in place. The preferred alternative from an economic standpoint is the use of the Southern Outfall at Wellawatta for ocean disposal. This alternative includes building a sewage

collection system that discharges into a pumping station equipped with mechanical bar screens and grit removal systems. The purpose of this preliminary treatment system is to remove large solids, obstructive matter and grit (sand and other inert matter) in order to prevent clogging of the outfall ports and to minimize the abrasion of the pumps. The pumping station would discharge the sewage into the outfall's junction box. The pipe connecting the pumping station and the junction box would be a 900 mm diameter ductile iron pipe. The routing of the pipe would be preferably through the existing drainage canals rights of way to minimize construction cost. A schematic diagram of the pretreatment and pumping station is shown on **Figure 6-1**.

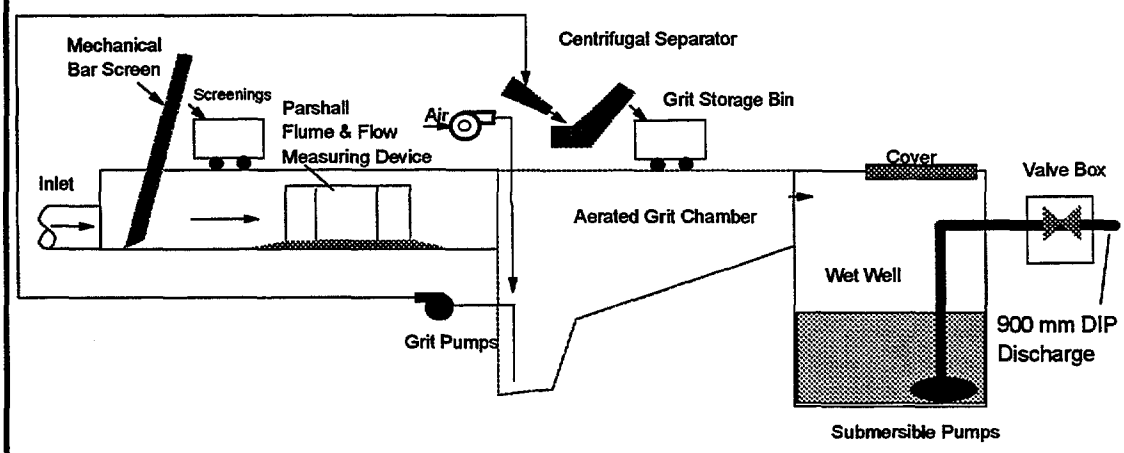


FIGURE 6-1 SCHEMATIC DIAGRAM OF THE PROPOSED SYSTEM

More specific design parameters of the proposed system are included in Annex 1.

The sewer system will be expanded to include new developments. This may require updating the pumps to yield a higher capacity. The main sewer trunk lines and forced main would be sized initially with a capacity to handle the year 2020 flows.

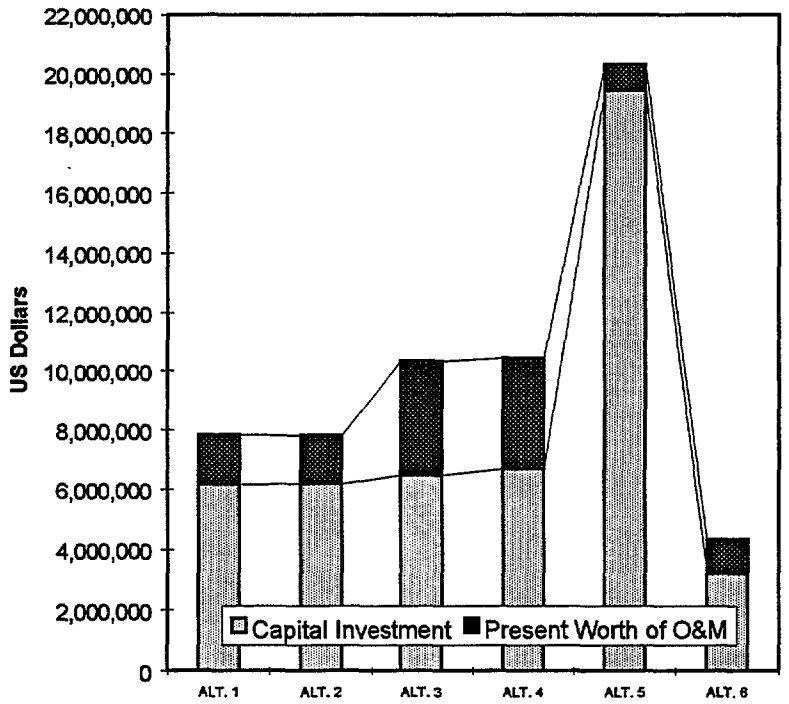
SECTION 7. PRELIMINARY RECOMMENDED PLAN - SHORT-TERM PROJECTS – KOTTE U.C. AREA

The objective of this section is to indicate the recommended plan for further discussion during the next project phase.

7.1 PREFERRED ALTERNATIVE

The following figure shows the present worth cost analysis summary for the treatment alternatives. All these alternatives require a collection system. The cost of the collection system is not included in the figure.

Summary of Present Worth Analysis of Wastewater Treatment Alternatives, for the Kotte U.C. to the Year 2000



For comparison of alternatives, the analysis assumes a 20 year period at 10 percent interest with no salvage value. Based on this cost-effectiveness analysis, the preferred alternative is Alternative 6 – preliminary treatment and disposal via the Wellawatta Southern Outfall. This alternative includes preliminary treatment (screening and grit removal) and pumping from southwest Kotte UC to the junction box of the Southern Outfall via a 4 kilometer long, 900 mm diameter ductile iron pipe. The second best option is Alternative 2 - the trickling filter system with wetland disposal. The cost of the collection system adds about 8.12 million USD or MRs 487.2 to the cost of the treatment plant system.

7.2 CAPITAL INVESTMENT

The capital investment is as follows:

Sewer Collection System = 8.12 million USD or MRs 487.2
Outfall Disposal = 3.20 million USD or MRs 192.0
Total = 11.32 million USD or MRs 679.2

7.3 OPERATION AND MANINTENANCE REQUIREMENTS

The proposed system includes the sewer collection system, preliminary treatment and ocean disposal. The sewer system O&M would require a staff of about 30 people to handle the sewers, force mains and lift stations in Kotte UC. The staff would be based at the Kotte U.C. public works. The pumping station would require a workforce of about 12 employees including: one general manager, two operators, five laborers, one mechanic, one electrician, and one laboratory technician. An administration building will be necessary to house the staff. In addition, the O&M staff would require vehicles, basic utilities (water, telephone, electricity, etc.), spare parts, and supplies.

7.4 OPERATION AND MAINTENANCE COSTS

The O&M costs for the first year of operation is summarized in **Table 7-1**.

Table 7-1 First Year O&M Costs

Item	Sewage Collection	Pumping Station and Piping	Total
Chemicals	0	0	0
Labor Costs	97,380	171,492	268,872
Spare Parts & Repairs	66,600	22,200	88,800
Electricity	53,611	13,143	66,754
Materials & Other Supplies	12,500	7,500	20,000
Other Utilities	2,167	839	3,006
Operator's fees	41,729	55,138	96,867
Total annual cost in US$	273,988	270,312	544,300
Total annual cost in Rs	16,439,256	16,218,725	32,657,981

The expected first-year annual O&M cost of the proposed system is about $0.54 million USD or MRs 16.2.

7.5 POSSIBLE TARIFFS SCENARIOS

The average annual debt service on the amortized capital of $11.32 million USD or MRs 679.2, is about $1.3 million USD or MRs 68.75 (at 10 percent interest for 20 years without salvage value). Therefore, the total minimum annual revenues to make this project pay back the debt is about $1.85 million USD or MRs 110.6 (assuming that the first year O&M cost is constant through the life of the project).

User Charge Scenario. An average annual sewer tariff would be about $61.70 USD or Rs 3,702 per customer (assuming 30,000 customers). This would be invoiced with the water bill. The unit cost is estimated at about $0.211 USD or about Rs 12.67 per m^3 (based on 24,000 m^3 per day).

Property Tax. If the tariff is charged to the property taxes, and assuming there are about 1,500 ha. of private property in Kotte U.C., the average additional taxes of property would be about $0.123 USD/ m^2 or about Rs 7.4 per m^2 per year (or about Rs 187 per Perch). This represents less than 0.21 percent of the average value of land (Rs 90,000 per Perch) in the Kotte U.C. area.

7.6 ADDITIONAL WORK REQIRED

In order to move the project forward to the implementation stage, we recommend the following additional work to complete the Feasibility Study and Master Plan for Kotte U.C.:

- Water Quality Monitoring and Sampling Program
- Comprehensive Community Survey
- Environmental Assessment
- Public Participation Plan
- More Detailed Financial Plan
- Pre-qualification Package
- Municipal Code for On-site Systems

The scopes of work for conducting the above recommended activities are included in Annex 3.

ANNEX 1

COST ESTIMATES
AND
ENGINEERING CALCULATIONS

COST ESTIMATES

COLLECTION SYSTEM - JAYAWARDENEPURA KOTTE
Construction Cost Summary

Exchange Rate: 60 Rs/ per US$

Series	Designation	Price, Rs			US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	329,613,390	329,613,390	0	$5,493,557	$5,493,557	$0
200	Lift Stations	26,890,287	4,756,287	22,134,000	$448,171	$79,271	$368,900
1300	Engineering - Design	28,520,294	0	0	$475,338	$0	$0
	TOTAL FOR EACH PART	385,023,971	334,369,677	22,134,000	$6,417,066	5,572,828	368,900
	Mobilization, OH & Profit	96,255,993			$1,604,267		
	Equipment shipping and handling	5,976,180			$99,603		
	Land Cost	0			$0		
	TOTAL	**487,256,144**			**$8,120,936**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipement delivery, storage and startup factor =	17.00%	
Reinforce steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$0
Labor Costs	$97,380
Spare Parts & Repairs	$66,600
Electricity	$53,611
Cost per connected Hp	
Materials & Other Supplies	$12,500
Other Utilities	$2,167
Operator's fees	$41,729
Total annual cost in US$	**$273,988**
Total annual cost in, Rs	*16,439,256*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$953,882
Average annual O&M cost		$228,389
Average annual cost		$1,182,272
Average annual flow m^3/yr.	11,787,302	
Total average unit cost, $/m^3		$0.100
Total average unit cost, Rs/m^3		6.02

Project financing 20 years *

Rate 10.00% percent*

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs, millions	US$
Present Worth Construction Cost	487	8,120,936
Present Worth O&M Cost	117	1,947,704
Tota; Present Worth	604	10,068,640

Land cost 0 Ha @ US$ $330,000 **$0**

ALTERNATIVE 1 - TRICKLING FILTER
Construction Cost Summary

Exchange Rate: 60 Rs/ per US$

Series	Designation	Price Rs			Price US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	18,393,169	18,393,169	0	$306,553	$306,553	$0
200	Pre-treatment	17,009,868	9,071,868	7,938,000	$283,498	$151,198	$132,300
300	Primary treatment	34,416,540	8,544,540	25,872,000	$573,609	$142,409	$431,200
400	Biological treatment	50,028,914	13,383,914	36,645,000	$833,815	$223,065	$610,750
500	Secondary clarifiers	31,008,862	8,496,862	22,512,000	$516,814	$141,614	$375,200
600	Chlorine Contact	21,475,066	4,675,066	16,800,000	$357,918	$77,918	$280,000
700	Digesters	15,490,577	5,350,577	10,140,000	$258,176	$89,176	$169,000
900	Sludge Drying Beds	2,643,598	1,850,638	792,960	$44,060	$30,844	$13,216
1000	Administration and Laboratory building	7,559,229	4,619,229	2,940,000	$125,987	$76,987	$49,000
1100	Electrical general	22,260,000	0	22,260,000	$371,000	$0	$371,000
1200	Miscellaneous-Landscaping	600,000	0	600,000	$10,000		$10,000
1300	Engineering - Design	17,670,866	0	0	$294,514	$0	$0
	TOTAL FOR EACH PART	238,556,687	74,385,861	146,499,960	$3,975,945	1,239,764	2,441,666
	Mobilization, OH & Profit	59,639,172			$993,986		
	Equipment shipping and handling	39,554,989			$659,250		
	Land Cost	32,670,000			$544,500		
	TOTAL	**370,420,848**			**$6,173,681**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipment delivery, storage and startup factor =	17.00%	
Reinforced steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$34,040
Labor Costs	$181,072
Spare Parts & Repairs	$22,200
Electricity	$19,747
Cost per connected Hp	$0
Materials & Other Supplies	$7,500
Other Utilities	$887
Operator's fees	$68,020
Total annual cost in US$	**$333,466**
Total annual cost in, Rs	*20,007,972*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$725,158
Average annual O&M cost		$183,980
Average annual cost		$909,138
Average annual flow m^3/yr.	11,787,302	
Average COD load, kg/yr.	5,620,023	
Average TSS load, kg/yr.	2,883,906	
Total average unit cost, $/$m^3$		$0.077
Total average unit cost, Rs/m^3		4.63

Project financing 20 years *

Rate 10.00% *

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs, millions	US$
Present Worth Construction Cost	370	6,173,681
Present Worth O&M Cost	100	1,667,160
Total Present Worth	470	7,840,841

Land cost = 1.65 Ha @ US$ $330,000 **$544,500**

ALTERNATIVE 2 - TRICKLING FILTER WITH WETLANDS
Construction Cost Summary

Exchange Rate: 60 Rs/ per US$

Series	Designation	Price Rs			Price US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	24,914,371	24,914,371	0	$415,240	$415,240	$0
200	Pre-treatment	17,009,868	9,071,868	7,938,000	$283,498	$151,198	$132,300
300	Primary treatment	34,416,540	8,544,540	25,872,000	$573,609	$142,409	$431,200
400	Biological treatment	66,828,914	13,383,914	53,445,000	$1,113,815	$223,065	$890,750
700	Digesters	15,490,577	5,350,577	10,140,000	$258,176	$89,176	$169,000
900	Sludge Drying Beds	2,643,598	1,850,638	792,960	$44,060	$30,844	$13,216
1000	Administration and Laboratory building	7,559,229	4,619,229	2,940,000	$125,987	$76,987	$49,000
1100	Electrical general	22,260,000	0	22,260,000	$371,000	$0	$371,000
1200	Miscellaneous-Landscaping	600,000	0	600,000	$10,000		$10,000
1300	Engineering - Design	15,337,848	0	0	$255,631	$0	$0
	TOTAL FOR EACH PART	207,060,943	67,735,136	123,987,960	$3,451,016	1,128,919	2,066,466
	Mobilization, OH & Profit	51,765,236			$862,754		
	Equipment shipping and handling	33,476,749			$557,946		
	Land Cost	79,200,000			$1,320,000		
	TOTAL	**371,502,928**			**$6,191,715**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipment delivery, storage and startup factor =	17.00%	
Reinforced steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$34,040
Labor Costs	$171,492
Spare Parts & Repairs	$22,200
Electricity	$19,484
Cost per connected Hp	$0
Materials & Other Supplies	$7,500
Other Utilities	$839
Operator's fees	$65,486
Total annual cost in US$	**$321,041**
Total annual cost in Rs	*19,262,466*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$727,277
Average annual O&M cost		$188,985
Average annual cost		$916,261
Average annual flow m^3/yr.	11,787,302	
Average COD load, kg/yr.	5,620,023	
Average TSS load, kg/yr.	2,883,906	
Total average unit cost, $/m^3		$0.078
Total average unit cost, Rs/m^3		4.66

Project financing 20 years *

Rate 10.00% *

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs millions	US$
Present Worth Construction Cost	372	6,191,715
Present Worth O&M Cost	98	1,627,687
Total Present Worth	469	7,819,402

Land cost = 4 Ha @ US$ $330,000 **$1,320,000**

ALTERNATIVE 3 - CONVENTIONAL ACTIVATED SLUDGE
Construction Cost Summary

Exchange Rate: 60 Rs/ per US$

Series	Designation	Price Rs			Price US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	20,185,022	20,185,022	0	$336,417	$336,417	$0
200	Pre-treatment	26,269,232	18,331,232	7,938,000	$437,821	$305,521	$132,300
300	Primary treatment	33,981,258	8,109,258	25,872,000	$566,354	$135,154	$431,200
400	Biological treatment	47,982,292	18,330,292	29,652,000	$799,705	$305,505	$494,200
500	Secondary clarifiers	28,197,200	5,685,200	22,512,000	$469,953	$94,753	$375,200
600	Chlorine Contact	19,252,671	2,452,671	16,800,000	$320,878	$40,878	$280,000
700	Digesters	14,178,402	4,038,402	10,140,000	$236,307	$67,307	$169,000
900	Sludge Drying Beds	2,503,127	1,710,167	792,960	$41,719	$28,503	$13,216
1000	Administration and Laboratory building	7,107,516	4,167,516	2,940,000	$118,459	$69,459	$49,000
1100	Electrical general	22,260,000	0	22,260,000	$371,000	$0	$371,000
1200	Miscellaneous-Landscaping	600,000	0	600,000	$10,000		$10,000
1300	Engineering - Design	17,801,338	0	0	$296,689	$0	$0
	TOTAL FOR EACH PART	240,318,057	83,009,760	139,506,960	$4,005,301	1,383,496	2,325,116
	Mobilization, OH & Profit	60,079,514			$1,001,325		
	Equipment shipping and handling	37,666,879			$627,781		
	Land Cost	49,500,000			$825,000		
	TOTAL	**387,564,451**			**$6,459,408**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipment delivery, storage and startup factor =	17.00%	
Reinforced steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$34,040
Labor Costs	$185,232
Spare Parts & Repairs	$15,410
Electricity	$177,427
Cost per connected Hp	$0
Materials & Other Supplies	$7,500
Other Utilities	$978
Operator's fees	$525,734
Total annual cost in US$	**$946,321**
Total annual cost in Rs	*56,779,240*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$758,720
Average annual O&M cost		$479,424
Average annual cost		$1,238,144
Average annual flow m^3/yr.	11,787,302	
Average COD load, kg/yr.	5,620,023	
Average TSS load, kg/yr.	2,883,906	
Total average unit cost, $/m^3		$0.105
Total average unit cost, Rs/m^3		6.30

Project financing 20 years *
Rate 10.00% *

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs millions	US$
Present Worth Construction Cost	388	6,459,408
Present Worth O&M Cost	232	3,860,450
Total Present Worth	619	10,319,858

Land cost = 1.5 Ha @ US$ $550,000 **$825,000**

ALTERNATIVE 4 - EXTENDED AERATION
Construction Cost Summary

Exchange Rate: 55 Rs/ per US$

Series	Designation	Price Rs			Price US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	17,727,855	17,727,855	0	$322,325	$322,325	$0
200	Pre-treatment	15,592,379	8,315,879	7,276,500	$283,498	$151,198	$132,300
400	Biological treatment	88,985,454	49,022,454	39,963,000	$1,617,917	$891,317	$726,600
500	Secondary clarifiers	28,424,790	7,788,790	20,636,000	$516,814	$141,614	$375,200
600	Chlorine Contact	19,685,477	4,285,477	15,400,000	$357,918	$77,918	$280,000
700	Digesters	14,199,695	4,904,695	9,295,000	$258,176	$89,176	$169,000
900	Sludge Drying Beds	2,423,298	1,696,418	726,880	$44,060	$30,844	$13,216
1000	Administration and Laboratory building	6,929,293	4,234,293	2,695,000	$125,987	$76,987	$49,000
1100	Electrical general	20,405,000	0	20,405,000	$371,000	$0	$371,000
1200	Miscellaneous-Landscaping	550,000	0	550,000	$10,000		$10,000
1300	Engineering - Design	17,193,859	0	0	$312,616	$0	$0
	TOTAL FOR EACH PART	232,117,099	97,975,860	116,947,380	$4,220,311	1,781,379	2,126,316
	Mobilization, OH & Profit	58,029,275			$1,055,078		
	Equipment shipping and handling	31,575,793			$574,105		
	Land Cost	45,375,000			$825,000		
	TOTAL	**367,097,167**			**$6,674,494**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipment delivery, storage and startup factor =	17.00%	
Reinforced steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$34,040
Labor Costs	$185,232
Spare Parts & Repairs	$12,262
Electricity	$177,427
Cost per connected Hp	$0
Materials & Other Supplies	$7,500
Other Utilities	$978
Operator's fees	$106,969
Total annual cost in US$	**$524,408**
Total annual cost in Rs	*28,842,421*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$783,984
Average annual O&M cost		$461,442
Average annual cost		$1,245,426
Average annual flow m^3/yr.	11,787,302	
Average COD load, kg/yr.	5,620,023	
Average TSS load, kg/yr.	2,883,906	
Total average unit cost, $/m^3		$0.106
Total average unit cost, Rs/m^3		5.81

Project financing 20 years *
Rate 10.00% *

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs, millions	US$
Present Worth Construction Cost	367	6,674,494
Present Worth O&M Cost	207	3,763,171
Total Present Worth	574	10,437,665

Land cost = 2.5 Ha @ US$ $330,000 **$825,000**

ALTERNATIVE 5 - FACULTATIVE LAGOONS
Construction Cost Summary

Exchange Rate: 60 Rs/ per US$

Series	Designation	Price Rs			Price US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	58,659,600	58,659,600	0	$977,660	$977,660	$0
200	Pre-treatment	17,009,868	9,071,868	7,938,000	$283,498	$151,198	$132,300
1000	Administration and Laboratory building	6,719,229	4,619,229	2,100,000	$111,987	$76,987	$35,000
1100	Electrical general	13,440,000	0	13,440,000	$224,000	$0	$224,000
1200	Miscellaneous-Landscaping	600,000	0	600,000	$10,000		$10,000
1300	Engineering - Design	7,714,296	0	0	$128,572	$0	$0
	TOTAL FOR EACH PART	104,142,993	72,350,697	24,078,000	$1,735,717	1,205,845	401,300
	Mobilization, OH & Profit	26,035,748			$433,929		
	Equipment shipping and handling	6,501,060			$108,351		
	Land Cost	1,029,600,000			$17,160,000		
	TOTAL	**1,166,279,801**			**$19,437,997**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipment delivery, storage and startup factor =	17.00%	
Reinforced steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$0
Labor Costs	$106,512
Spare Parts & Repairs	$8,234
Electricity	$12,814
Cost per connected Hp	$0
Materials & Other Supplies	$7,500
Other Utilities	$641
Operator's fees	$34,774
Total annual cost in US$	**$170,475**
Total annual cost in Rs	*10,228,522*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$2,283,180
Average annual O&M cost		$101,599
Average annual cost		$2,384,778
Average annual flow m^3/yr.	11,787,302	
Average COD load, kg/yr.	5,620,023	
Average TSS load, kg/yr.	2,883,906	
Total average unit cost, $/m^3		$0.202
Total average unit cost, Rs/m^3		12.14

Project financing 20 years *

Rate 10.00% *

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs, millions	US$
Present Worth Construction Cost	1,166	19,437,997
Present Worth O&M Cost	52	867,102
Total Present Worth	1,218	20,305,098

Land cost = 52 Ha @ US$ $330,000 **$17,160,000**

NATIVE 6 - PRELIMINARY TREATMENT AND DISPOSAL VIA THE WELLAWATTA (SOUTHERN) OUTFALL
Construction Cost Summary

Exchange Rate: 60 Rs/ per US$

Series	Designation	Price Rs			Price US$		
		Total	Construction	Equipment	Total	Construction	Equipment
100	General Civil	89,412,060	89,412,060	0	$1,490,201	$1,490,201	$0
200	Pre-treatment	20,137,400	3,295,400	16,842,000	$335,623	$54,923	$280,700
1000	Administration and Laboratory building	7,559,229	4,619,229	2,940,000	$125,987	$76,987	$49,000
1100	Electrical general	4,632,600	0	4,632,600	$77,210	$0	$77,210
1200	Miscellaneous-Landscaping	600,000	0	600,000	$10,000		$10,000
1300	Engineering - Design	9,787,303	0	0	$163,122	$0	$0
	TOTAL FOR EACH PART	132,128,592	97,326,689	25,014,600	$2,202,143	1,622,111	416,910
	Mobilization, OH & Profit	33,032,148			$550,536		
	Equipment shipping and handling	6,753,942			$112,566		
	Land Cost	19,800,000			$330,000		
	TOTAL	**191,714,682**			**$3,195,245**		

Includes Equipment Installation Cost =	40.00%	of equipment cost
Contractor's mobilization, overhead & profit =	25.00%	of civil work
Equipment markup by contractor =	10.00%	of equipment cost
Equipment delivery, storage and startup factor =	17.00%	
Reinforced steel in water tanks	100 kg/m^3	of concrete
Reinforced steel in other structures	70 kg/m^3	of concrete
Engineering cost	8.00%	percent of total construction cost

First Year O&M Costs

Item	Annual Cost
Chemicals	$0
Labor Costs	$171,492
Spare Parts & Repairs	$22,200
Electricity	$13,143
Cost per connected Hp	$0
Materials & Other Supplies	$7,500
Other Utilities	$839
Operator's fees	$55,138
Total annual cost in US$	**$270,312**
Total annual cost in Rs	*16,218,725*

Average Cost of Treatment

Item	Amount	Annual cost
Amortization of Capital Cost *		$375,312
Average annual O&M cost		$120,261
Average annual cost		$495,573
Average annual flow m^3/yr.	11,787,302	
Average COD load, kg/yr.	5,620,023	
Average TSS load, kg/yr.	2,883,906	
Total average unit cost, $/m^3		$0.042
Total average unit cost, Rs/m^3		2.52

Project financing 20 years *

Rate 10.00% *

PRESENT WORTH COST

Rate = 10.00%

Cost Item	Rs, millions	US$
Present Worth Construction Cost	192	3,195,245
Present Worth O&M Cost	69	1,149,331
Total Present Worth	261	4,344,576

Land cost = 1 Ha @ US$ $330,000 **$330,000**

UNIT PRICES -SRI LANKA, JANUARY 1997

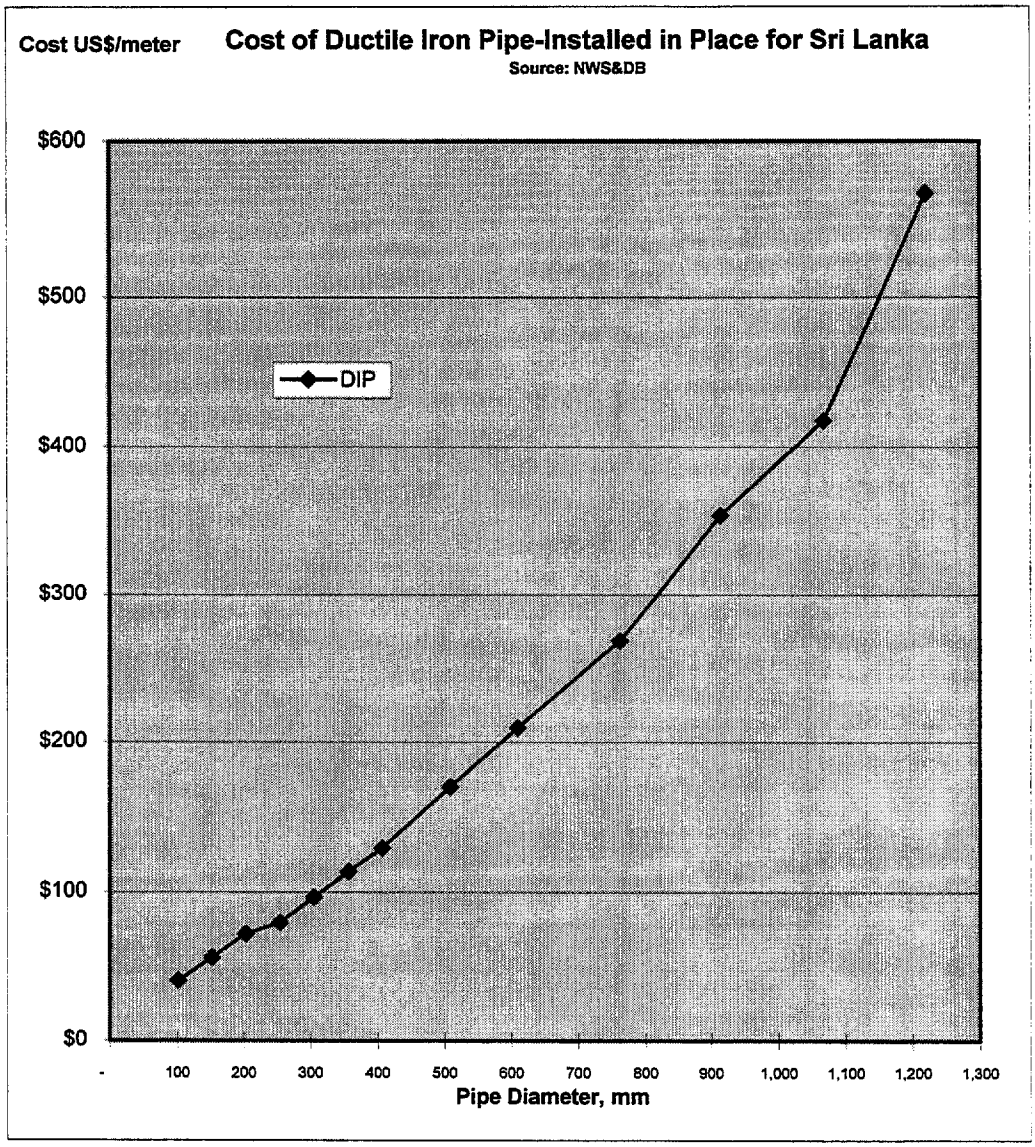
Price No.	ITEM	Units	Unit Price (in US $)	Unit Price Rs/
1	Earth excavation in trenches including dewatering			
	a) 0.00 m to 3.00 m deep	m3	4.00	240
	b) 3.00 m to 6.00 m deep	m3	5.33	320
2	Disposal of excavated material to berms on site as directed by the Engineer	m3	1.16	70
3	Place a compact backfill in trenches with material from the excavations			
	a) 0.00 m to 3.00 m deep	m3	1.78	107
	b) 3.00 m to 6.00 m deep	m3	2.14	128
	Place a compact backfill from stock piles at structures	m3	2.62	157
4	Mass excavation by machines for structures including dewatering, handtrimming,			
	disposal in any material except rock.	m3	2.00	120
5	Earth excavation by hand	m3	2.18	131
6	Supply, place and compact Granular material:			
	a) in trenches	m3	1.76	106
	b) elsewhere	m3	1.89	113
8	Supply, haul, place and compact approved inorganic fill for backfilling of trenches			
	and other excavations	m3	1.78	107
9	Mass rock excavation by wedging and drilling including disposal or rock (solid			
	ledge rock and boulders over 1/2 m3 in volume).	m3	38.33	2,300
10	Mass rock excavation by blasting including disposal of rock (solid ledge rock			
	boulders over 1/2 m3 in volume). The price shall be "extra-over". To item 4.	m3	67.27	4,036
11	Supply and install timber sheathing and shoring.	m2	83.13	4,988
12	Concrete supplied in place and cured:			
	a) for footings and slabs on grade	m3	96.50	5,790
	b) for colomns, piers and beans	m3	116.69	7,001
	c) for walls	m3	125.60	7,536
	d) for slabs above grade	m3	104.58	6,275
13	50 mm thick, blinding supplied in place, finished and cured.	m3	101.82	6,109
14	f'c=210 kg/cm concrete supplied in place:			
	a) for pipe encasement and bedding	m3	101.82	6,109
	b) for fill concrete	m3	90.91	5,455
15	Waterstop:			
	a) construction joints	Lin m	33.45	2,007
	b) expansion joints	Lin m	33.45	2,007
16	Formwork in place, including stripping:			
	a) for footings and slabs on grade	m2	22.04	1,322
	b) for columns, piers and beams	m2	21.09	1,265
	c) for walls	m2	24.73	1,484
	d) for slabs above grade	m2	26.18	1,571

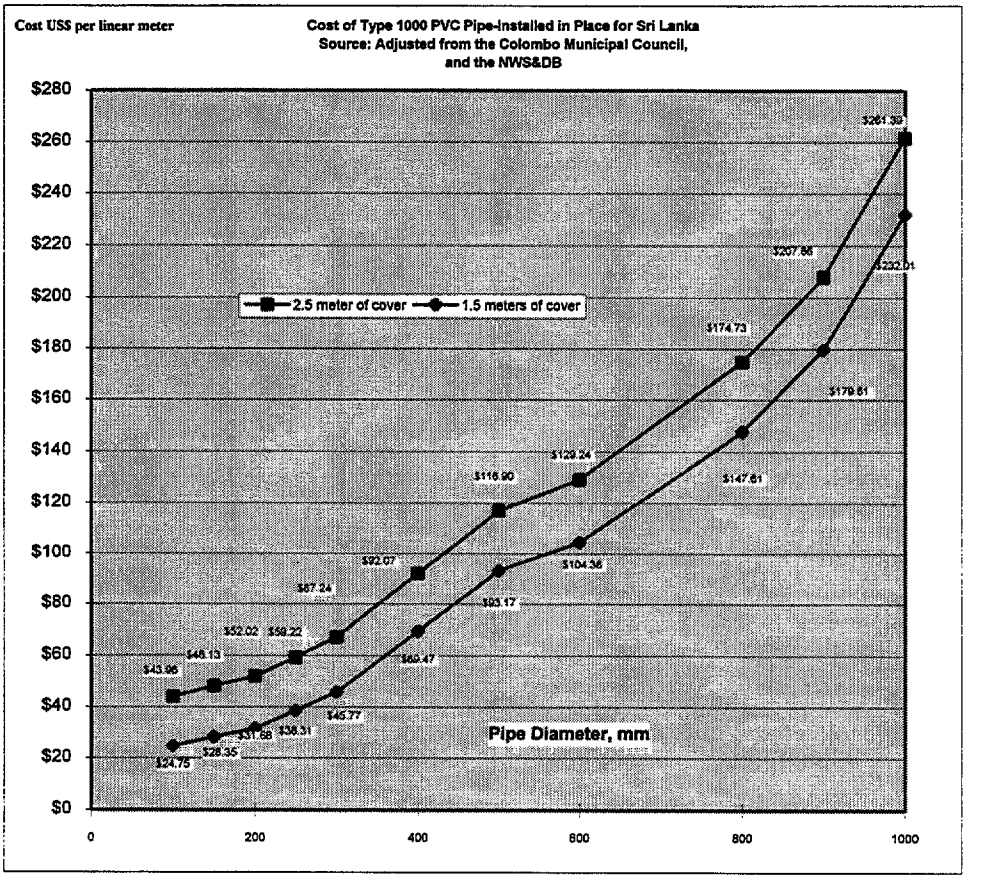
Price No.	ITEM	Units	Unit Price (in US $)	Rs/
17	Reinforcing steel supplied in place	kg	0.80	48
18	Finish formed concrete surface:			
	a) Local mortar for concrete finishes- exterior	m2	2.04	122
	b) Local mortar for concrete finishes (interior)	m2	2.91	175
19	Supply and install 100 mm concrete block.	m2	6.00	360
	Supply and install 150 mm concrete block	m2	5.33	320
	Supply and install 200 mm concrete block	m2	4.84	290
	Supply and install anodizel aluminium handrail as specified.	lm	120.00	7,200
	Structural steel supply and installed.	kg	0.80	48
	Supply and install painting to:			
	a) masonry and concrete	m2	4.07	244
	b) wallboard and plaster painting system	m2	2.18	131
20	Clearing vegetation	m2	0.36	22
21	Gravel	m3	5.50	330
22	Sand	m3	4.50	270

60.00 Rs/US$

Labor Costs	Units	Unit cost, US	Unit cost, Rs/h
Management	hrs	$6.00	360
Training personnel (foreign)	hrs	$75.00	4,500
Operators	hrs	$2.00	120
Laborers	hrs	$1.00	60
Mechanics	hrs	$2.00	120
Electricians	hrs	$2.00	120
Lab. Technicians	hrs	$2.15	129
Chemicals			
Chlorine	kg	$0.75	45
Aluminum Sulfate	kg	$0.46	27
Electricity	kW-Hr.	$0.0600	3.60

Land cost in Kotte	m^2	$33.00	1,980
Land cost in Kotte	Ha.	$330,000	19,800,000


Cost US$/meter
Cost of Ductile Iron Pipe-Installed in Place for Sri Lanka
Source: NWS&DB
$600
$500
$400
$300
$200
$100
$0
DIP
-
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
1,300
Pipe Diameter, mm


Cost US$ per linear meter
Cost of Type 1000 PVC Pipe-Installed in Place for Sri Lanka
Source: Adjusted from the Colombo Municipal Council,
and the NWS&DB
$280
$260
$240
$220
$200
$180
$160
$140
$120
$100
$80
$60
$40
$20
$0
0
200
400
600
800
1000
2.5 meter of cover
1.5 meters of cover
Pipe Diameter, mm
$43.96
$48.13
$52.02
$59.22
$67.24
$92.07
$116.90
$129.24
$174.73
$207.86
$261.39
$24.75
$28.35
$31.68
$36.31
$45.77
$69.47
$93.17
$104.36
$147.61
$179.61
$232.01

9p

ENGINEERING CALCULATIONS

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ENVIROSOFT- ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 1 Trickling Filter

By: EFA

TRICKLING FILTER

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day		
Total suspended solids (TSS)	200	mg/l				
Design population	155,300					

RECTANGULAR PRIMARY CLARIFIERS

Hydraulic Loading	28.5	M^3/m^2/day	700	GPD/ft2
Area	926	m^2	9,964	ft^2
Number of units	2			
Length to width ratio	4			
Sidewater Depth, m	5.5	m	17.49	ft.
Total volume	5,094	m3		
Length	43.0	m	136.9	ft.
Width	10.8	m	34.2	ft.
Hydraulic Loading at peak daily flow	35.6	M^3/m^2/day	875	GPD/ft2
Hydraulic Loading at peak hourly flow	57.0	M^3/m^2/day	1,400	GPD/ft2
Estimated Concrete volume	560	m^3	732	cu. yards.
Slab	324	m^3	424	cu. yards.
Walls	236	m^3	309	cu. yards.

Influent pumps

Number	6			
Duty pumps	4			
Equalized flow	26,400	m^3/day	6.97	MGD
Flow each	76	L/s	1,211	GPM
	275	m^3/hr.		
THD	6.55	m	21.5	ft.
Pump efficiency	75.0%			
Motor efficiency	90.0%			
Power input required	7.3	kW	9.7	hp
Actual commercial size	7.5	kW	10.0	
Total power requirements	29.8	kW	40.0	hp

HIGH RATE TRICKLING FILTER(s)

Ambient temperature	25	°C	77	°F		
Number of filters	1		1			
Flow to each trickling filter	26,400	m^3/day	6.97	MGD	4,844	GPM
Hydraulic loading	53.8	$m^3/day/m^2$	1,320	gpd/ft^2		
Hydraulic loading	0.62	$L/s/m^2$	0.92	GPM/ft^2		
Area per filter	491.2	m^2	5,284	ft^2		
Filter diameter	25.0	m	82.04	ft.		
Depth of media	4.89	m	16.0	ft.		
Media volume per filter	2,402	m^3	84,751	cu. ft.		
Estimated BOD_5 removal in primary tanks	25%					
BOD_5 Loading to trickling filter	1.65	kg BOD_5/m^3/day				
	102.6	Lbs of BOD_5/ 1,000 ft^3 /day				
Treatability factor, K	0.08					
Media constant, n	0.50					
BOD_5 in the influent			150	mg/l		
BOD_5 in the filter effluent without recycle			29	mg/l		
Recycle flow, %	0%					
Filter efficiency without recycle	80.7%					
Estimated concrete volume	740	m^3	967	cu. yards.		
Slab	467	m^3	611	cu. yards.		
Walls	273	m^3	356	cu. yards.		

Use of Recycle

Recycle ratio (R/Q)	0.50			
Influent concentration			109	mg/l
Effluent concentration			21	mg/l
Filter efficiency with recycle	85.9%			

Recycle pumps

Number	4			
Duty pumps	2			
Recycle flow	13,200	m^3/day	3.49	MGD
Flow each	76	L/s	1,211	GPM
	275	m^3/hr.		
THD	6.41	m	21.0	ft.
Pump efficiency	70.0%			
Motor efficiency	90.0%			
Power input required	5.3	kW	7.2	hp
Actual commercial size	5.6	kW	7.5	
Total power requirements	11.2	kW	15.0	hp

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RECTANGULAR FINAL CLARIFIERS

Hydraulic Loading	28.5	M^3/m^2/day	700	GPD/ft2
Total average flow	26,400	m^3/day	6.97	MGD
Area	926	m^2	9,964	ft^2
Number of units	2			
Length to width ratio	4			
Sidewater Depth, m	5	m	15.9	ft.
Length	43.0	m	136.9	ft.
Width	10.8	m	34.2	ft.
Hydraulic Loading at peak daily flow	35.6	M^3/m^2/day	875	GPD/ft2
Hydraulic Loading at peak hourly flow	57.0	M^3/m^2/day	1,400	GPD/ft2
Estimated Concrete volume	541	m^3	707	cu. yards.
Slab	324	m^3	424	cu. yards.
Walls	217	m^3	283	cu. yards.

Chlorine Contact Chamber

Inputs

Y = effluent concentration at end of time t	10,000	MPN/100 ml
Yo = influent concentration	1.00E+06	MPN/100 ml
c = chlorine residual at end of time t	0.5	mg/l

Outputs

t = time of contact	15.8	minutes		
Volume of contact chamber at ave. flow	290	m^3	10,243	Ft^3
Chamber dimensions				
Inputs:				
d = dispersion coefficient	0.02			
K = coefficient on nonideality	5			
D = longitudinal dispersion coefficient	0.08			
W/H = width to depth ratio	2			
Calculations				
Number of compartments	5			
H = depth of the chamber	1.5	m	4.92	ft.
Area per chamber	38.7	m^2		
ß = Length to width ratio	20			
W = width of the chamber	1.4	m	4.56	ft.
L = Length of the chamber	27.8	m	91.25	ft.
μ = velocity of flow	0.146	m/s		
Estimated concrete volume	339	m^3	443	cu. yards.
Slab	58	m^3	76	cu. yards.
Walls	281	m^3	368	cu. yards.

6b

ENVIROSOFT- ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 1 Trickling Filter

SLUDGE TREATMENT - WITH RECYCLE IN THE TRICKLING FILTER

HIGH RATE - COMPLETELY MIXED ANAEROBIC DIGESTER

Average daily plant flow	26,400	M^3/day	6.97	MGD
Peak daily plant flow	33,000	M^3/day	8.72	MGD
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day
Biochemical Oxygen Demand (BOD_5)	200	mg/l		
Total suspended solids (TSS)	200	mg/l		
Sludge production rate	0.30	kg/kg BOD_5 removed		
Estimated BOD_5 removal in filter without recycle	80.7%			
Estimated BOD_5 removal in filter with recycle	85.9%			
Estimated BOD_5 removal in primary tanks	25%			
Estimated TSS removal in primary tanks	40%			
% volatile solids in TF sludge	83.33%			

Sludge Production

Primary sludge concentration	3.00%			
Primary sludge TSS loading	2,108	kg/day	4,638	lb/day
Primary sludge flow	70.3	m^3/day	0.019	MGD
% VSS in primary sludge	40%			
TF sludge concentration	1.00%			
TF sludge loading	1,019	kg/day	2,241	lbs/day
TF sludge flow	102	m^3/day	0.027	MGD
Combined sludge concentration	1.82%		1.82%	
Combined sludge flow	172	m^3/day	0.045	
Combined sludge loading	3,127	kg/day	6,879	lbs/day
Combined sludges VSS concentrarion	65.64%			

Sludge Thickener

Hydraulic Loading	4.1	M^3/m^2/day	100	GPD/ft2
Area	42.3	m^2	454.8	ft^2
Number of units	1			
Diameter	5.8	m	18.9	ft.
Sidewater Depth	3.0	m	9.84	ft.
Sludge loading	74.0	Kg/m^2/day	15.1	lb/ft2/day
Underflow solids	4.0%			
Solids capture efficiency	75.0%			
Solids in the underflow	2,345	kg/day	5,159	lbs/day
Solids flow to the digester	58.63	m^3/day	0.015	MGD
VS in the underflow	1,539	kg/day	3,387	lbs/day
Estimated concrete volume	38.3	m^3	50.0	cu. yards.
Slab on grade	13.1	m^3	17.1	cu. yards.
Walls	25.2	m^3	32.9	cu. yards.

Anaerobic Digester Design

Detention time	20.0	days		
Number of units	1			
Volume for each tank	1,173	m^3	41,375	ft^3
Depth	7	m	23.0	ft.
Depth to diameter ratio	0.48			
Area	168	m^2	1,802	ft^2
Diameter	14.6	m	47.9	ft.
VS loading rate	1.31	$kg/m^3/day$	0.08	$lbs/ft^3/day$
Gas production	800	L/kg VS dest	12.83	scf/lb Vs destroyed
Reduction in VS	40.0%			
VS destroyed in digester	616	kg/day	1,355	lb/day
Gas production rate	493	m^3/day	36,488	scf/day
Solid in the digester effluent	1,421	kg/day	3,127	lb/day
Effluent solids concentration	2.42%			
VS in the digester effluent	616	kg/day	1,355	lb/day
Estimated concrete volume	185.75	m^3	242.8	cu. yards.
Slabs on grade	134.00		175.1	cu. yards.
Walls	51.75		67.6	cu. yards.

SLUDGE DRYING BEDS

Annual rainfall	2000.0	mm/yr	78.74	inches/yr.
Annual Evaporation	2500.0	mm/yr	98.43	inches/yr.
Net evaporation	500.0	mm/yr	19.7	inches/yr.
Sludge Load	1,729	kg/day	3,804	lb/day
Annual sludge load	631,188	kg/yr.	1,388,615	lb/yr.
Area loading	73.4	$kg/m^2/yr$	15.0	$lb/ft^2/yr$
Desired solids concentration	50%			
Depth of sludge put on the beds	300	mm	12.24	inches
Initial concentration	2.42%			
Concentration after initial drainage	15%			
Initial water applied to the beds	292.73	mm	11.95	inches
Loss due to initial drainage	48.5	mm	1.98	inches
Total water loss	14.5	mm	0.59	inches
Rate of moisture loss in the sand beds	75%			
Rate of rainfall absorved by the sludge	57%			
Required evaporative loss	33.9	mm	1.39	inches
Evaporative rate	1,875.0	mm	76.53	inches
Rainfall absorved by the sludge	1,140.0	mm	46.53	inches
Net evaporation of sludge water	735.0	mm/yr.	30.00	inches/yr.
Annual cycle of bed useage	21.65	times/yr.	21.65	times/yr.
Factor of safety for seasonal weather	25%			
Area requirements	497	m^2	5,344	ft^2
No. of bays	8			
Area per bay	62.1	m^2	668.0	ft^2
Width	6.1	m	20.0	ft.
Length	10.2	m	33.4	ft.
Volume of gravel	149	m^3	194.8	cu. yards.
Volume of sand	223.5	m^3	292.1	cu. yards.
Unit loading	4.06	kg/cap/yr.	8.94	lb/cap/yr.
Estimated concrete requirements	171.5	m^3	224.1	cu. yards.
Slabs on grade	124.2		162.3	cu. yards.
Walls	47.3	m^3	61.8	cu. yards.

ENVIROSOFT- ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City
Location : Sri Lanka
Alternative 1 Trickling Filter
By: EFA

Headworks Design

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					

Bar - Screens

Mechanically Cleaned Screens				
Screen spacing	19.1	mm	0.75	inches
Number of channels	1			
By-pass channel	1			
Dimensions				
Depth to width ratio at ave. flow	1.33			
Depth of water at ave. flow	0.74	m	2.41	ft.
Width	0.55	m	1.82	ft.
Screen bar thickness	9.53	mm	0.375	inches
Number of bars	18			
Channel area at average flow	0.407	m2	4.38	ft. 2
Channel area at peak flow	0.611	m2		
Approach velocity at ave. flow	0.750	m/s	2.46	ft./s
Approach velocity at peak hourly flow	1	m/s	3.28	ft./s
Depth of water at peak flow	1.10	m	3.62	ft.
Channel width	0.55	m	1.82	ft.
Head Loss at average flow				
$h_L = ß\ (w/b)^{\wedge 1.3333}\ h_v \sin a$				
ß = a bar shape factor	2.42			
w = maximum cross-sectional area wi	0.010	m	0.374	inches
b = minimum clear spacing of the bars	0.0191	m	0.752	inches
Velocity of flow prior to screens	0.407	m/s	1.34	ft./s
Velocity throught the screens	0.799	m/s	2.62	ft./s
h_v = velocity head of flow approaching the	0.034	m	0.11	ft.
a = angle of the rack with the horizont	60			
Head loss at ave. flow	0.028	m	0.09	ft.
Velocity of flow prior to screens	1.000	m/s	3.28	ft./s
Velocity throught the screens	1.449	m/s	4.75	ft./s
h_v = velocity head of flow approaching the	0.080	m/s	0.26	ft./s
Head loss at maximum flow	0.066	m	0.22	ft.

Grit Removal System

Process Type : Spiral Flow

Detention time at maximum flowrate	3.00	min.		
Detention time at average flowrate	6.00	min.		
Dimensions				
Diameter	4.27	m	14.00	ft

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ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 2 Trickling Filter with Wetlands

By: EFA

TRICKLING FILTER

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day		
Total suspended solids (TSS)	200	mg/l				
Design population	155,300					

RECTANGULAR PRIMARY CLARIFIERS

Hydraulic Loading	28.5	M^3/m^2/day	700	GPD/ft2
Area	926	m^2	9,964	ft^2
Number of units	2			
Length to width ratio	4			
Sidewater Depth, m	5.5	m	17.49	ft.
Total volume	5,094	m3		
Length	43.0	m	136.9	ft.
Width	10.8	m	34.2	ft.
Hydraulic Loading at peak daily flow	35.6	M^3/m^2/day	875	GPD/ft2
Hydraulic Loading at peak hourly flow	57.0	M^3/m^2/day	1,400	GPD/ft2
Estimated Concrete volume	560	m^3	732	cu. yards.
Slab	324	m^3	424	cu. yards.
Walls	236	m^3	309	cu. yards.

Influent pumps

Number	6			
Duty pumps	4			
Equalized flow	26,400	m^3/day	6.97	MGD
Flow each	76	L/s	1,211	GPM
	275	m^3/hr.		
THD	6.55	m	21.5	ft.
Pump efficiency	75.0%			
Motor efficiency	90.0%			
Power input required	7.3	kW	9.7	hp
Actual commercial size	7.5	kW	10.0	
Total power requirements	29.8	kW	40.0	hp

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HIGH RATE TRICKLING FILTER(s)

Ambient temperature	25	°C	77	°F		
Number of filters	1		1			
Flow to each trickling filter	26,400	m^3/day	6.97	MGD	4,844	GPM
Hydraulic loading	61.1	$m^3/day/m^2$	1,500	gpd/ft^2		
Hydraulic loading	0.71	$L/s/m^2$	1.04	GPM/ft^2		
Area per filter	432.2	m^2	4,650	ft^2		
Filter diameter	23.5	m	76.96	ft.		
Depth of media	4.89	m	16.0	ft.		
Media volume per filter	2,114	m^3	74,581	cu. ft.		
Estimated BOD_5 removal in primary tanks	25%					
BOD_5 Loading to trickling filter	1.87	kg BOD_5/m^3/day				
	116.6	Lbs of BOD_5/ 1,000 ft^3 /day				
Treatability factor, K	0.08					
Media constant, n	0.50					
BOD_5 in the influent			150	mg/l		
BOD_5 in the filter effluent without recycle			32	mg/l		
Recycle flow, %	0%					
Filter efficiency without recycle	78.7%					
Estimated concrete volume	669	m^3	874	cu. yards.		
Slab	413	m^3	539	cu. yards.		
Walls	256	m^3	335	cu. yards.		

Use of Recycle

Recycle ratio (R/Q)	0.25			
Influent concentration			126	mg/l
Effluent concentration			27	mg/l
Filter efficiency with recycle	82.0%			

Recycle pumps

Number	4			
Duty pumps	2			
Recycle flow	6,600	m^3/day	1.74	MGD
Flow each	38	L/s	605	GPM
	137.5	m^3/hr.		
THD	6.41	m	21.0	ft.
Pump efficiency	70.0%			
Motor efficiency	90.0%			
Power input required	2.7	kW	3.6	hp
Actual commercial size	5.6	kW	7.5	
Total power requirements	11.2	kW	15.0	hp

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CONSTRUCTED WETLANDS

BOD Removal

Total average flow	26,400	m^3/day	6.97	MGD
BOD max month/BOD annual average	1.3			
Monthly Ave. Influent BOD Concentration	35	mg/l		
Annual Ave. BOD Concentration	27	mg/l		
Outlet target BOD Concentration	40	mg/l		
Required annual BOD outlet concentration	30.8	mg/l		
First Order Aerial Rate Constant, K	60	m/yr		
Background BOD Concentration	2	mg/l		
ln (Ci-C*/Ce-C*)	0.14			
Area Required	2.2	Ha.		

Chlorine Contact Chamber

Inputs

Y = effluent concentration at end of time t	10,000	MPN/100 ml		
Yo = influent concentration	1.00E+06	MPN/100 ml		
c = chlorine residual at end of time t	0.5	mg/l		

Outputs

t = time of contact	15.8	minutes		
Volume of contact chamber at ave. flow	290	m^3	10,243	Ft^3
Chamber dimensions				
Inputs:				
d = dispersion coefficient	0.02			
K = coefficient on nonideality	5			
D = longitudinal dispersion coefficient	0.08			
W/H = width to depth ratio	2			
Calculations				
Number of compartments	5			
H = depth of the chamber	1.5	m	4.92	ft.
Area per chamber	38.7	m^2		
ß = Length to width ratio	20			
W = width of the chamber	1.4	m	4.56	ft.
L = Length of the chamber	27.8	m	91.25	ft.
μ = velocity of flow	0.146	m/s		
Estimated concrete volume	339	m^3	443	cu. yards.
Slab	58	m^3	76	cu. yards.
Walls	281	m^3	368	cu. yards.

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ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 2 Trickling Filter with Wetlands

SLUDGE TREATMENT - WITH RECYCLE IN THE TRICKLING FILTER

HIGH RATE - COMPLETELY MIXED ANAEROBIC DIGESTER

Average daily plant flow	26,400	M^3/day	6.97	MGD
Peak daily plant flow	33,000	M^3/day	8.72	MGD
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day
Biochemical Oxygen Demand (BOD_5)	200	mg/l		
Total suspended solids (TSS)	200	mg/l		
Sludge production rate	0.30	kg/kg BOD_5 removed		
Estimated BOD_5 removal in filter without recycle	78.7%			
Estimated BOD_5 removal in filter with recycle	82.0%			
Estimated BOD_5 removal in primary tanks	25%			
Estimated TSS removal in primary tanks	40%			
% volatile solids in TF sludge	83.33%			

Sludge Production

Primary sludge concentration	3.00%			
Primary sludge TSS loading	2,108	kg/day	4,638	lb/day
Primary sludge flow	70.3	m^3/day	0.019	MGD
% VSS in primary sludge	40%			
TF sludge concentration	1.00%			
TF sludge loading	972	kg/day	2,139	lbs/day
TF sludge flow	97	m^3/day	0.026	MGD
Combined sludge concentration	1.84%		1.84%	
Combined sludge flow	168	m^3/day	0.044	
Combined sludge loading	3,080	kg/day	6,777	lbs/day
Combined sludges VSS concentrarion	65.15%			

Sludge Thickener

Hydraulic Loading	4.1	M^3/m^2/day	100	GPD/ft2
Area	41.1	m^2	442.6	ft^2
Number of units	1			
Diameter	5.7	m	18.6	ft.
Sidewater Depth	3.0	m	9.84	ft.
Sludge loading	74.9	Kg/m^2/day	15.3	lb/ft2/day
Underflow solids	4.0%			
Solids capture efficiency	75.0%			
Solids in the underflow	2,310	kg/day	5,083	lbs/day
Solids flow to the digester	57.76	m^3/day	0.015	MGD
VS in the underflow	1,505	kg/day	3,312	lbs/day
Estimated concrete volume	37.7	m^3	49.2	cu. yards.
Slab on grade	12.8	m^3	16.7	cu. yards.

Walls	24.9	m^3	32.5	cu. yards.

Anaerobic Digester Design

Detention time	20.0	days		
Number of units	1			
Volume for each tank	1,155	m^3	40,763	ft^3
Depth	7	m	23.0	ft.
Depth to diameter ratio	0.48			
Area	165	m^2	1,775	ft^2
Diameter	14.5	m	47.6	ft.
VS loading rate	1.30	$kg/m^3/day$	0.08	$lbs/ft^3/day$
Gas production	800	L/kg VS dest	12.83	scf/lb Vs destroyed
Reduction in VS	40.0%			
VS destroyed in digester	602	kg/day	1,325	lb/day
Gas production rate	482	m^3/day	35,681	scf/day
Solid in the digester effluent	1,407	kg/day	3,096	lb/day
Effluent solids concentration	2.44%			
VS in the digester effluent	602	kg/day	1,325	lb/day
Estimated concrete volume	183.38	m^3	239.7	cu. yards.
Slabs on grade	132.02		172.5	cu. yards.
Walls	51.36		67.1	cu. yards.

SLUDGE DRYING BEDS

Annual rainfall	2000.0	mm/yr	78.74	inches/yr.
Annual Evaporation	2500.0	mm/yr	98.43	inches/yr.
Net evaporation	500.0	mm/yr	19.7	inches/yr.
Sludge Load	1,708	kg/day	3,758	lb/day
Annual sludge load	623,505	kg/yr.	1,371,710	lb/yr.
Area loading	73.4	$kg/m^2/yr$	15.0	$lb/ft^2/yr$
Desired solids concentration	50%			
Depth of sludge put on the beds	300	mm	12.24	inches
Initial concentration	2.44%			
Concentration after initial drainage	15%			
Initial water applied to the beds	292.69	mm	11.95	inches
Loss due to initial drainage	48.7	mm	1.99	inches
Total water loss	14.6	mm	0.60	inches
Rate of moisture loss in the sand beds	75%			
Rate of rainfall absorved by the sludge	57%			
Required evaporative loss	34.1	mm	1.39	inches
Evaporative rate	1,875.0	mm	76.53	inches
Rainfall absorved by the sludge	1,140.0	mm	46.53	inches
Net evaporation of sludge water	735.0	mm/yr.	30.00	inches/yr.
Annual cycle of bed useage	21.55	times/yr.	21.55	times/yr.
Factor of safety for seasonal weather	25%			
Area requirements	493	m^2	5,305	ft^2
No. of bays	8			
Area per bay	61.6	m^2	663.1	ft^2
Width	6.1	m	20.0	ft.
Length	10.1	m	33.1	ft.

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Volume of gravel	148	m^3	193.3	cu. yards.
Volume of sand	221.9	m^3	290.0	cu. yards.
Unit loading	4.01	kg/cap/yr.	8.83	lb/cap/yr.
Estimated concrete requirements	170.4	m^3	222.7	cu. yards.
Slabs on grade	123.3		161.1	cu. yards.
Walls	47.1	m^3	61.6	cu. yards.

ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 2 Trickling Filter with Wetlands

By: EFA

Headworks Design

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					

Bar - Screens

Mechanically Cleaned Screens				
Screen spacing	19.1	mm	0.75	inches
Number of channels	1			
By-pass channel	1			
Dimensions				
Depth to width ratio at ave. flow	1.33			
Depth of water at ave. flow	0.74	m	2.41	ft.
Width	0.55	m	1.82	ft.
Screen bar thickness	9.53	mm	0.375	inches
Number of bars	18			
Channel area at average flow	0.407	m2	4.38	ft. 2
Channel area at peak flow	0.611	m2		
Approach velocity at ave. flow	0.750	m/s	2.46	ft./s
Approach velocity at peak hourly flow	1	m/s	3.28	ft./s
Depth of water at peak flow	1.10	m	3.62	ft.
Channel width	0.55	m	1.82	ft.
Head Loss at average flow				
$h_L = ß\ (w/b)^{\wedge 1.3333}\ h_v \sin a$				
ß = a bar shape factor	2.42			
w = maximum cross-sectional area wi	0.010	m	0.374	inches
b = minimum clear spacing of the bars	0.0191	m	0.752	inches
Velocity of flow prior to screens	0.407	m/s	1.34	ft./s
Velocity throught the screens	0.799	m/s	2.62	ft./s
h_v = velocity head of flow approaching the	0.034	m	0.11	ft.
a = angle of the rack with the horizont	60			
Head loss at ave. flow	0.028	m	0.09	ft.
Velocity of flow prior to screens	1.000	m/s	3.28	ft./s
Velocity throught the screens	1.449	m/s	4.75	ft./s
h_v = velocity head of flow approaching the	0.080	m/s	0.26	ft./s
Head loss at maximum flow	0.066	m	0.22	ft.

Grit Removal System

Process Type : Spiral Flow				
Detention time at maximum flowrate	3.00	min.		
Detention time at average flowrate	6.00	min.		
Dimensions				
Diameter	4.27	m	14.00	ft

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ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City
Location : Sri Lanka

By: EFA

ALTERNATIVE 3 - CONVENTIONAL - ACTIVATED SLUDGE PROCESS DESIGN

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	36,960	M^3/day	9.76	MGD	6,781	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	1.40					
Biochemical Oxygen Demand (BOD5)	5,271	kg/day	11,596	lb/day		
Biochemical Oxygen Demand (BOD5)	199	MG/L				
Total suspended solids (TSS)	5,272	kg/day	11,598	lb/day		
Total suspended solids (TSS)	199	MG/L				
Design Population	155,300					

CIRCULAR PRIMARY CLARIFIER(s)

Hydraulic Loading	28.5	M^3/m^2/day	700	GPD/ft^2
Total average flow	26,400	m^3/day	6.97	MGD
Area	926	m^2	9,964	ft^2
Number of units	2		2	
Diameter	19.1	m	62.5	ft.
Sidewater Depth	4	m	13.12	ft.
Hydraulic loading at daily peak flow	35.6	M^3/m^2/day	875	GPD/ft^2
Hydraulic Loading at peak hourly flow	39.9	M^3/m^2/day	980	GPD/ft2
Estimated concrete volume	448	m^3	586	cu. yards.
Walls	325	m^3	425	cu. yards.
Slabs	123	m^3	160	cu. yards.

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AERATION TANK(s) (NEW)

Detention time at average flow, hr.	7					
Recycle flow, %	50%					
Recycle flow	13,200	m^3/day	3.49	MGD	2,422	GPM
Flow to the aeration tank	39,600	m^3/day	10.46	MGD	7,266	GPM
Basin Volume	11,550	m^3	407,571	ft^3		
Basin depth	5	m	16.4	ft.		
Total Basin Area	2,310	m^2	24,852	ft^2		
Number of basins	4		4			
Area of each basin	578	m^2	6,213	ft^2		
Length to width ratio	4		4			
Width	12.0	m	39.4	ft.		
Length	48.1	m	157.6	ft.		
Estimated BOD_5 removal in primary tanks	25%					
BOD_5 Loading to aeration tanks	0.34	kg/m^3/day	21.3	Lbs of BOD_5/ 1,000 ft^3 /day		
MLVSS in aeration tank	3,000	mg/l				
Mass of MLVSS in aeration tank	34,650	kg.	76,230	lbs		
F/M ratio	0.11	kg of BOD_5/kg MLVSS				
Estimated concrete volume	1,698	m^3	2,219	cu. yards.		
Slab	924	m^3	1,208	cu. yards.		
Walls	774	m^3	1,011	cu. yards.		

CIRCULAR SECONDARY CLARIFIER(s)

Hydraulic Loading	28.5	M^3/m^2/day	700	GPD/ft^2
Total average flow with recycle	39,600	m^3/day	10.46	MGD
Area	1,389	m^2	14,946	ft^2
Number of units	2		2	
Diameter	23.4	m	76.6	ft.
Sidewater Depth	5.5	m	18.04	ft.
Hydraulic loading at daily peak flow	35.6	M^3/m^2/day	875	GPD/ft^2
Hydraulic Loading at peak hourly flow	36.1	M^3/m^2/day	887	GPD/ft2
Estimated concrete volume	689	m^3	900	cu. yards.
Walls	507	m^3	663	cu. yards.
Slabs	182	m^3	237	cu. yards.

Chlorine Contact Chamber

Inputs				
Y = effluent concentration at end of time t	1	MPN/100 ml		
Yo = influent concentration	1.00E+04	MPN/100 ml		
c = chlorine residual at end of time t	1	mg/l		
Outputs				
t = time of contact	89.3	minutes		
Volume of contact chamber at ave. flow	1,638	m^3	57,785	Ft^3
Chamber dimensions				
Inputs:				
d = dispersion coefficient	0.02			
K = coefficient on nonideality	5			
D = longitudinal dispersion coefficient	0.02			
W/H = width to depth ratio	2			
Calculations				
Number of compartments	5			
ß = Length to width ratio	35			
W = width of the chamber	4.5	m		
L = Length of the chamber	31.8	m		
H = depth of the chamber	2.3	m		
μ = velocity of flow	0.030	m/s		
Estimated concrete volume	574	m^3	750	cu. yards.
Wall	285.1	m^3	373	cu. yards.
Slab	288.5	m^3	377	cu. yards.

ENVIROSOFT- ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City
Location : Sri Lanka 1/0/00

By: EFA
ALTERNATIVE 3 - CONVENTIONAL - ACTIVATED SLUDGE PROCESS DESIGN

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	36,960	M^3/day	9.76	MGD	6,781	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	1.40					
Biochemical Oxygen Demand (BOD_5)	5,271	kg/day	11,596	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	5,272	kg/day	11,598	lb/day		
Total suspended solids (TSS)	200	mg/l				
Estimated BOD_5 removal in primary tanks	25%					
Design MLVSS	3,000	mg/l				

TANK DIMENSIONS

Total Basin Area	2,310	m^2	24,852	ft^2		
Number of basins	4		4			
Basin Volume	11,550	m^3	407,571	ft^3	3.05	MG
Basin depth	5	m	16.4	ft.		
Area of each basin	578	m^2	6,213	ft^2		
Length to width ratio	4		4			
Width	12.0	m	39.4	ft.		
Length	48.1	m	157.6	ft.		

OXYGEN REQUIREMENTS

Estimated BOD_5/BOD_u ratio	0.70	
Cell yield coefficient, a	0.70	
Endogenous respiration factor, K_d	0.06	
Estimated BOD_5 removal in aeration tanks	0.80	
O_2 Uptake rate	372	mg/l of O_2 /day
Oxygen requirements	4,298	kg of O_2 /day
	9,456	lb of O_2 /day
Air Volume	21,389	m^3 / day 754,753 ft^3 /day

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Diffused Aeration

Manufacturer's oxygen transfer efficiency,E	10.0%			
Design ambient temperature	28	°C	82	°F
Elevation	30	m amsl	98	ft. amsl
Atmospheric pressure	1.036	kg/ cm2	14.70	psi
Specific weight of ambient air at 25°C	0.87	kg/m^3	0.054	lbs/ft^3
Discharge pressure	0.500	kg/ cm2	7.10	psig
Pressure losses(estimated)	0.093	kg/ cm2	1.32	psig
Total discharge pressure	0.593	kg/ cm2	8.42	psig
alpha			0.90	
Beta			0.95	
Cs, Oxygen saturation at 20°C, 750mm			8.95	mg/l
Cs, Oxygen saturation at 25°C, 750mm			8.19	mg/l
Pressure at the bottom, Pb			23.12	psi
% of O_2			0.189	mol
Air out at 79% N			0.979	mol
O_2 at the top			19.31%	
$C_{sm,}$ Oxygen saturation at midpoint, 20°C			11.17	mg/l
$C_{sm,}$ Oxygen saturation at midpoint, 25°C			10.22	mg/l
Ave. dissolved oxygen concentration, Cl			1.00	mg/l
Actual Efficiency, E			8.2%	
Air flow			6,374	scfm
Weight of flow of air at 25 oC			5.9	lb/sec
Compressor efficiency	70%			
Required power	160	kW	215	hp
Flow per diffuser	0.05	m^3 / min.	1.59	cfm
Number of diffusers			4,000	each
Number of diffusers per basin			1,000	each
Number of headers			50	each
Diffusers per header			20	each
Air volume			1.316	ft^3/gal
			1,319	ft^3/lb BOD removed
			0.53	hp/1,000 ft^3

NUMBER OF SURFACE AERATORS (ALTERNATIVE)			16	
Size	15	kW	20	Hp
Total power	239	kW	320	Hp
	0.021	kW/m^3	0.79	hp/1,000 ft^3

ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

By:

SLUDGE TREATMENT

HIGH RATE - COMPLETELY MIXED ANAEROBIC DIGESTER

Average daily flow	26,400	M^3/day	6.97	MGD		
Peak daily flow	33,000	M^3/day	8.72	MGD		
Biochemical Oxygen Demand (BOD_5)	5,271	kg/day	11,596	lb/day		
Total suspended solids (TSS)	5,272	kg/day	11,598	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	200	mg/l				
Basin Volume	11,550	m^3	407,571	ft^3	3.05	MG
Cell yield coefficient, a	0.70					
Endogenous respiration factor, K_d	0.04					
Estimated BOD_5 removal in aeration tanks	0.80					
Estimated BOD_5 removal in primary tanks	25.00%					
Estimated TSS removal in primary tanks	40.00%					
Estimated primary sludge concentration	2.50%					
Primary sludge loading	2,108.8	kg/day	4,639	lb/day		
Primary sludge flow	84.22	m3/day	0.0223	mgd		
Design MLVSS	3,000	mg/l				
% volatile solids in WAS	83.33%					
% volatile solids in Primary Sludge	40.00%					
Waste activated sludge concentration	1.00%					
Waste activated sludge loading	1,565	kg/day	3,443	lbs/day		
WAS flow	156	m^3/day	0.041	MGD		
Total combined sludge	3,674	kg/day	8,082	lbs/day		
Total combined sludge	241	m^3/day	0.064	mgd		
Total combined sludge	1.53%		1.53%			
Total volatile solids in combined sludge	2,147.6	kg/day	4,725	lbs/day		
% volatile solids in Combined Sludge	58.5%					

Sludge Thickener

Hydraulic Loading	4.1	$M^3/m^2/day$	100	GPD/ft2
Area	59.1	m^2	636.0	ft^2
Number of units	1			
Diameter	6.8	m	22.3	ft.
Sidewater Depth	3.0	m	9.84	ft.
Sludge loading	26.5	$Kg/m^2/day$	5.4	$lb/ft^2/day$
Underflow solids	4.0%			
Solids capture efficiency	90.0%			
Solids in the underflow	3,306	kg/day	3,099	lbs/day
Solids flow to the digester	82.66	m^3/day	0.009	MGD
Estimated concrete volume	34.2	m^3	44.7	cu. yards.
Slab	17.7	m^3	23.2	cu. yards.
Walls	16.5	m^3	21.6	cu. yards.

Anaerobic Digester Design

Detention time	20.0	days		
Number of units	1			
Volume for each tank	685	m^3	24,160	ft^3
Depth	7	m	23.0	ft.
Depth to diameter ratio	0.63			
Area	98	m^2	1,052	ft^2
Diameter	11.2	m	36.6	ft.
VS loading rate	1.65	$kg/m^3/day$	0.10	$lbs/ft^3/day$
Gas production	800	L/kg VS destroy	12.83	scf/lb Vs destroyed
Reduction in VS	60.0%			
VS destroyed in digester	677.92	kg/day	1,491	lb/day
Gas production rate	542	m^3/day	40,173	scf/day
Solid in the digester effluent	2,628	kg/day	5,783	lb/day
Effluent solids concentration	3.18%			
VS in the digester effluent	11	kg/day	23	lb/day
Estimated concrete volume	117.67	m^3	153.8	cu. yards.
Slabs on grade	78.25		102.3	cu. yards.
Walls	39.42		51.5	cu. yards.

SLUDGE DRYING BEDS

Annual rainfall	2000.0	mm/yr	78.74	inches/yr.
Annual Evaporation	2500.0	mm/yr	98.43	inches/yr.
Net evaporation	500.0	mm/yr	19.7	inches/yr.
Sludge Load	2,628	kg/day	5,783	lb/day
Annual sludge load	959,372	kg/yr.	2,110,619	lb/yr.
Area loading	73.4	$kg/m^2/yr$	15.0	$lb/ft^2/yr$
Desired solids concentration	50%			
Depth of sludge put on the beds	300	mm	12.24	inches
Initial concentration	3.18%			
Concentration after initial drainage	15%			
Initial water applied to the beds	290.46	mm	11.86	inches
Loss due to initial drainage	63.6	mm	2.60	inches
Total water loss	19.1	mm	0.78	inches
Rate of moisture loss in the sand beds	75%			
Rate of rainfall absorved by the sludge	57%			
Required evaporative loss	44.5	mm	1.82	inches
Evaporative rate	1,875.0	mm	76.53	inches
Rainfall absorved by the sludge	1,140.0	mm	46.53	inches
Net evaporation of sludge water	735.0	mm/yr.	30.00	inches/yr.
Annual cycle of bed useage	16.51	times/yr.	16.51	times/yr.
Factor of safety for seasonal weather	25%			
Area requirements	990	m^2	10,653	ft^2
No. of bays	8			
Area per bay	123.8	m^2	1,331.6	ft^2
Width	6.1	m	20.0	ft.
Length	20.3	m	66.6	ft.
Volume of gravel	297	m^3	388.2	cu. yards.
Volume of sand	445.6	m^3	582.4	cu. yards.
Unit loading	6.18	kg/cap/yr.	13.59	lb/cap/yr.
Estimated concrete requirements	317.6	m^3	415.1	cu. yards.
Slabs on grade	247.6		323.5	cu. yards.
Walls	70.1	m^3	91.6	cu. yards.

Envirosoft-Engineering & Scicne Inc.

Project Name : Kotte Capital City
Location : Sri Lanka

Date: 2/3/97
By: EFA

PIPING & PUMP STATION

Average daily flow	306	L/s	6.97	mgd	4,844	gpm
Peak daily flow	382	L/s	8.72	mgd	6,055	gpm
Peak hourly flow	428	L/s	9.76	mgd	6,781	gpm
Veocity at Ave. Flow	1.52	m/s	5.00	fps		
Static Head	8.00	m	26.24	ft	11.4	psi
Pipe area	0.20	m2	2.16	ft2		
Pipe diameter	506	mm	20	inches		
Veocity at peak daily flow	1.91	m/s	6.25	fps		
Friction factor, f	0.026					
Manning's roughness coefficient "n"	0.013					
Length of pipe	80	m	100	ft		
Friction head loss at ave. flow	0.19	m	0.62	ft.		
Minor losses at ave. flow	0.03	m	0.09	ft.		
Total dynamic head at Ave. flow	8.22	m	26.95	ft	11.7	psi
Friction head loss at max.. flow	0.29	m	0.97	ft.		
Minor losses at max. flow	0.04	m	0.14	ft.		
Total dynamic head at max. flow	8.34	m	27.35	ft	11.8	psi
Number of Pumps	4					
Duty pumps	3					
Overall efficiency	75%					
Flow each	101.85	L/s	2.32	mgd	1,615	gpm
Power	10.94	kW	15	Hp		
Commercial motor size	11.19	kW	15	Hp		
Total connected power	33.57	kW	45	Hp		
Pump station dimensions						
High water elevation	16.00	m				
Low water elevation	13.00	m				
Discharge elevation	25.05	m				
Bottom elevation	12.30	m				
Freeboard	2.8	m				
Width	6	m				
Length	6	m				
Depth	6.50	m				
Estimated Concrete volume	153	m^3	199	cu. yards.		
Slab & cover	98	m^3	128	cu. yards.		
Walls	55	m^3	71	cu. yards.		
Effective wet well volume	108.00	m^3	28,534	gallons		

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PRIMARY SLUDGE PUMPS

Type	Progressive Cavity			
Number of pumps	2			
Duty pumps	1			
Flow each	84.2	m3/day	84,221	l/d
Pumping rates	20%	of time		
Flow each	4.9	L/s	77.3	GPM
	18	m^3/hr.		
THD	10.00	m	32.8	ft.
Pump efficiency	72.0%			
Motor efficiency	90.0%			
Power input required	0.7	kW	0.99	Hp
Commercial size	0.7	kW	1.00	Hp
Total installed Hp requirements	1.5	kW	2.00	Hp

SECONDARY SLUDGE PUMPS

Type	Progressive Cavity			
Number of pumps	2			
Duty pumps	1			
Flow each	156.5	m3/day	156,491	l/d
Pumping rates	20%	of time		
Flow each	9.1	L/s	143.6	GPM
	33	m^3/hr.		
THD	10.00	m	32.8	ft.
Pump efficiency	72.0%			
Motor efficiency	90.0%			
Power input required	1.4	kW	1.84	Hp
Commercial size	1.9	kW	2.50	Hp
Total installed Hp requirements	3.7	kW	5.00	Hp

Thickened Sludge Pumps Pumps

Type	Progressive Cavity				
Number of pumps	2				
Duty pumps	1				
Flow each	240.7	m3/day	240,711	l/d	
Pumping rates	20%	of time			
Flow each	13.9	L/s	220.8	GPM	
	50	m^3/hr.			
THD	10.00	m	32.8	ft.	14 psi
Pump efficiency	75.0%				
Motor efficiency	90.0%				
Power input required	2.0	kW	2.72	Hp	
Commercial size	3.7	kW	5.00	Hp	
Total installed Hp requirements	7.5	kW	10.00	Hp	

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Return Activated Sludge Pumps (non-clog)

Type	Centrifugal				
Number of pumps	4				
Duty pumps	3				
Flow each	4,400.0	m3/day	4,400,000	l/d	
Pumping rates	100%	of time			
Flow each	50.9	L/s	807.3	GPM	
	183	m^3/hr.			
THD	15.00	m	49.2	ft.	21 psi
Pump efficiency	75.0%				
Motor efficiency	90.0%				
Power input required	11.1	kW	14.90	Hp	
Commercial size	14.9	kW	20.00	Hp	
Total installed Hp requirements	59.6	kW	80.00	Hp	

Grit Pumps (non-clog)

Type	Centrifugal				
Number of pumps	2				
Duty pumps	1				
Flow each	163.5	m3/day	163,500	l/d	
Pumping rates	20%	of time			
Flow each	9.5	L/s	150.0	GPM	
	34	m^3/hr.			
THD	26.00	m	85.3	ft.	37 psi
Pump efficiency	75.0%				
Motor efficiency	90.0%				
Power input required	3.6	kW	4.80	Hp	
Commercial size	3.7	kW	5.00	Hp	
Total installed Hp requirements	7.5	kW	10.00	Hp	

Pumps	Quantity	Capacity L/s each	Capacity GPM eac	Total Dynamic Head meters	Total Dynamic Head feet	Motor size Hp	Type
Pump Station	4	101.9	1,615	8.2	26.95	15.00	Verical Turbine Or Submersible
Primary Sludge Pumps	4	4.9	77	10.0	32.80		Centrifugal - Solids Handling
Primary Scum Ejectors	4	0.5	8	8.0	26.24	1.00	Vaccum Ejector
Return Activated Sludge Pumps	4	50.9	807	12.0	39.36	20.00	Centrifugal - Solids Handling
Grit Pumps	4	9.5	150	26.0	85.28	5.00	Centrifugal - Solids Handling
Combined Thickened Sludge Pumps	2	13.9	221	10.0	32.80	5.00	Progressive Cavity

ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 4 Extended Aeration Plant

By: EFA

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day		
Total suspended solids (TSS)	200	mg/l				
Design population	155,300					

AERATION TANK(s)

Detention time at average flow, hr.	18			
Recycle flow, %	50%			
Recycle flow	13,200	m^3/day	3.49	MGD	2,422	GPM
Flow to the aeration tank	39,600	m^3/day	10.46	MGD	7,266	GPM
Basin Volume	29,700	m^3	1,048,040	ft^3
Basin depth	5	m	16.4	ft.
Total Basin Area	5,940	m^2	63,905	ft^2
Number of basins	6		6	
Area of each basin	990	m^2	10,651	ft^2
Length to width ratio	4		4	
Width	15.7	m	51.6	ft.
Length	62.9	m	206.4	ft.
Estimated BOD_5 removal in primary tanks	0%			
BOD_5 Loading to aeration tanks	0.18	kg/m^3/day	11.1	Lbs of BOD_5/ 1,000 ft^3 /day
MLVSS in aeration tank	2,000	mg/l		
Mass of MLVSS in aeration tank	59,400	kg.	130,680	lbs
F/M ratio	0.09	kg of BOD_5/kg MLVSS		
Estimated concrete volume	3,679	m^3	4,808	cu. yards.
Slab	2,376	m^3	3,105	cu. yards.
Walls	1,303	m^3	1,702	cu. yards.

CIRCULAR SECONDARY CLARIFIER(s)

Hydraulic Loading	26.5	$M^3/m^2/day$	650	GPD/ft^2
Total average flow with recycle	39,600	m^3/day	10.46	MGD
Area	1,496	m^2	16,096	ft^2
Number of units	2		2	
Diameter	24.2	m	79.5	ft.
Sidewater Depth	5.5	m	18.04	ft.
Hydraulic loading at daily peak flow	33.1	$M^3/m^2/day$	813	GPD/ft^2
Hydraulic Loading at peak hourly flow	44.1	$M^3/m^2/day$	1,083	GPD/ft2
Estimated concrete volume	728	m^3	952	cu. yards.

Chlorine Contact Chamber

Inputs

Y = effluent concentration at end of time t	1	MPN/100 ml		
Yo = influent concentration	1.00E+04	MPN/100 ml		
c = chlorine residual at end of time t	1	mg/l		

Outputs

t = time of contact	89.3	minutes		
Volume of contact chamber at ave. flow	1,638	m^3	57,785	Ft^3

Chamber dimensions

Inputs:

d = dispersion coefficient	0.02	
K = coefficient on nonideality	5	
D = longitudinal dispersion coefficient	0.02	
W/H = width to depth ratio	2	

Calculations

Number of compartments	5			
ß = Length to width ratio	35			
W = width of the chamber	4.5	m		
L = Length of the chamber	31.8	m		
H = depth of the chamber	2.3	m		
μ = velocity of flow	0.030	m/s		
Estimated concrete volume	574	m^3	750	cu. yards.
Wall	285.1	m^3	373	cu. yards.
Slab	288.5	m^3	377	cu. yards.

ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 4 Extended Aeration Plant

By: EFA

EXTENDED AERATION - ACTIVATED SLUDGE PROCESS DESIGN - AERATION SYSTEM

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day		
Total suspended solids (TSS)	200	mg/l				
Estimated BOD_5 removal in primary tanks	0%					
Design MLVSS	2,000	mg/l				
Design population	155,300					

TANK DIMENSIONS

Total Basin Area	5,940	m^2	63,905	ft^2		
Number of basins	4		4			
Basin Volume	29,700	m^3	1,048,040	ft^3	7.84	MG
Basin depth	5	m	16.4	ft.		
Area of each basin	1,485	m^2	15,976	ft^2		
Length to width ratio	4		4			
Width	19.3	m	63.2	ft.		
Length	77.1	m	252.8	ft.		

OXYGEN REQUIREMENTS

Estimated BOD_5/BOD_u ratio	0.70	
Cell yield coefficient, a	0.70	
Endogenous respiration factor, K_d	0.06	
Estimated BOD_5 removal in aeration tank	0.80	
O_2 Uptake rate	219	mg/l of O_2 /day
Oxygen requirements	6,522	kg of O_2 /day
	14,348	lb of O_2 /day
Air Volume	32,456	m^3 / day ####### ft^3 /day

Diffused Aeration

Manufacturer's oxygen transfer efficiency,	8.0%			
Design ambient temperature	28	°C	82	°F
Elevation	30	m amsl	98	ft. amsl
Atmospheric pressure	1.036	kg/ cm2	14.70	psi
Specific weight of ambient air at 25°C	0.87	kg/m^3	0.054	lbs/ft^3
Discharge pressure	0.500	kg/ cm2	7.10	psig
Pressure losses(estimated)	0.093	kg/ cm2	1.32	psig
Total discharge pressure	0.593	kg/ cm2	8.42	psig
alpha			0.90	
Beta			0.95	
Cs, Oxygen saturation at 20°C, 750mm			8.95	mg/l
Cs, Oxygen saturation at 25°C, 750mm			8.19	mg/l
Pressure at the bottom, Pb			23.12	psi
% of O_2			0.193	mol
Air out at 79% N			0.983	mol
O_2 at the top			19.65%	
C_{sm}, Oxygen saturation at midpoint, 20°C			11.25	mg/l
C_{sm}, Oxygen saturation at midpoint, 25°C			10.29	mg/l
Ave. dissolved oxygen concentration, Cl			1.00	mg/l
Actual Efficiency, E			6.6%	
Air flow			12,081	scfm
Weight of flow of air at 25 oC			11.2	lb/sec
Compressor efficiency	70%			
Required power	303	kW	407	hp
Flow per diffuser	0.06	m^3 / min.	2.01	cfm
Number of diffusers			6,000	each
Number of diffusers per basin			1,500	each
Number of headers			60	each
Diffusers per header			25	each
Air volume			2.494	ft^3/gal
			1,876	ft^3/lb BOD removed
			0.39	hp/1,000 ft^3

NUMBER OF SURFACE AERATORS			16	
Size	22	kW	30	Hp
Total power	358	kW	480	Hp
	0.012	kW/m^3	0.46	hp/1,000 ft^3

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ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 4 Extended Aeration Plant

By:

SLUDGE TREATMENT

HIGH RATE - COMPLETELY MIXED ANAEROBIC DIGESTER

Average daily flow	26,400	M^3/day	6.97	MGD		
Peak daily flow	33,000	M^3/day	8.72	MGD		
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day		
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	200	mg/l				
Basin Volume	29,700	m^3	1,048,040	ft^3	7.84	MG
Cell yield coefficient, a	0.70					
Endogenous respiration factor, K_d	0.04					
Estimated BOD_5 removal in aeration tanks	0.80					
Estimated BOD_5 removal in primary tanks	0%					
Estimated TSS removal in primary tanks	40%					
Design MLVSS	2,000	mg/l				
% volatile solids in WAS	83.33%					
Waste activated sludge concentration	1.00%					
Waste activated sludge loading	574	kg/day	1,262	lbs/day		
WAS flow	57	m^3/day	0.015	MGD		

Sludge Thickener

Hydraulic Loading	2.0	M^3/m^2/day	50	GPD/ft2
Area	28.2	m^2	303.2	ft^2
Number of units	1			
Diameter	4.7	m	15.4	ft.
Sidewater Depth	3.0	m	9.84	ft.
Sludge loading	20.4	Kg/m^2/day	4.2	lb/ft^2/day
Underflow solids	4.0%			
Solids capture efficiency	75.0%			
Solids in the underflow	430	kg/day	947	lbs/day
Solids flow to the digester	10.76	m^3/day	0.003	MGD
Estimated concrete volume	30.0	m^3	39.2	cu. yards.

Anaerobic Digester Design

Detention time	20.0	days		
Number of units	1			
Volume for each tank	215	m^3	7,592	ft^3
Depth	3	m	9.8	ft.
Depth to diameter ratio	0.31			
Area	72	m^2	772	ft^2
Diameter	9.6	m	31.4	ft.
VS loading rate	2.00	$kg/m^3/day$	0.12	$lbs/ft^3/day$
Gas production	800	L/kg VS destroyed	12.83	scf/lb Vs destroyed
Reduction in VS	40.0%			
VS destroyed in digester	172	kg/day	379	lb/day
Gas production rate	138	m^3/day	10,200	scf/day
Estimated concrete volume	73.33	m^3	95.8	cu. yards.

SLUDGE DRYING BEDS

Sludge Load	258	kg/day	568	lb/day
Annual sludge load	94,237	kg/yr.	207,322	lb/yr.
Area loading	97.8	$kg/m^2/yr$	20.0	$lb/ft^2/yr$
Area requirements	964	m^2	10,366	ft^2
No. of bays	6			
Area per bay	160.6	m^2	1,727.7	ft^2
Width	8	m	26.2	ft.
Length	20.1	m	65.8	ft.
Volume of gravel	289	m^3	377.8	cu. yards.
Volume of sand	433.6	m^3	566.7	cu. yards.
Unit loading	17.88	kg/cap/yr.	39.34	lb/cap/yr.
Estimated concrete requirements	377.8	m^3	493.7	cu. yards.
Walls	88.7		115.9	cu. yards.
Slab	289.1		377.8	cu. yards.

ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City

Location : Sri Lanka

Alternative 5 Facultative Lagoons

By: EFA

DESIGN PARAMETERS

Average daily flow	26,400	M^3/day	6.97	MGD	4,844	GPM
Peak daily flow	33,000	M^3/day	8.72	MGD	6,055	GPM
Peak hourly flow	52,800	M^3/day	13.95	MGD	9,687	GPM
Peak/average flow ratio	1.25					
Peak hourly/average flow ratio	2.00					
Biochemical Oxygen Demand (BOD_5)	5,270	kg/day	11,594	lb/day		
Biochemical Oxygen Demand (BOD_5)	200	mg/l				
Total suspended solids (TSS)	5,270	kg/day	11,594	lb/day		
Total suspended solids (TSS)	200	mg/l				
Design population	155,300					

Lagoons - Three in Series

First Cell

Influent BOD5	200	mg/l				
BOD Loading Rate	101.05	Kg/Ha./da	90	Lb BOD5/acre/day		
BOD5 Loading to the first cell	5,270	KG/day	11,594.00	lbs/day		
BOD5 out	100	mg/l	220.00	lbs/day		
BOD5 Out	2,644	KG/day	5,817.07	lbs/day		
BOD5 Removal	49.91%					
Area Cell 1	26.13	Hectares	64.53	acres		
Average depth	2.20	meters	7.22	ft.		
Volume	574,791	m^3	20,282,961	ft^3	151.72	MG
Cell detention time	22	days				

Second Cell

Influent BOD5	100.00	mg/l				
BOD Loading Rate	78.59	Kg/Ha./da	70	Lb BOD5/acre/day		
BOD5 Loading to the second cell	2,644	KG/day	5,817.07	lbs/day		
BOD5 out	45	mg/l	99.00	lbs/day		
BOD5 Out	1,190	KG/day	2,617.68	lbs/day		
BOD5 Removal	55.00%					
Area Cell 2	15.14	Hectares	37.40	acres		
Average depth	1.50	meters	4.92	ft.		
Volume	227,098	m^3	8,013,724	ft^3	59.94	MG
Cell detention time	9	days				

Third Cell

Influent BOD5	45.00	mg/l				
BOD Loading Rate	67.36	Kg/Ha./da	60	Lb BOD5/acre/day		
BOD5 Loading to the second cell	1,190	KG/day	2,617.68	lbs/day		
BOD5 out	25	mg/l	55.00	lbs/day		
BOD5 Out	661	KG/day	1,454.27	lbs/day		
BOD5 Removal	44.44%					
Area Cell 2	9.81	Hectares	24.24	acres		
Average depth	1.00	meters	3.28	ft.		
Volume	98,129	m^3	3,462,720	ft^3	25.90	MG
Cell detention time	4	days				
Total volume	900,017	m^3	31,759,406	ft^3	237.56	MG
Total detention time	34	days				
Total Area Required	51.08	Hectares	126.17	acres		

Envirosoft-Engineering & Science Inc.
Main Pumping Station - Kotte U.C.

Project: Feasibility Study for Wastewater Management
Date: 2/3/97
By: EFA

ATLERNATIVE 6 - PUMPING STATION AND OUTFALL DISCHARGE

PIPING & PUMP STATION

Average daily flow	412	L/s	9.40	mgd	6,531	gpm	14.55 fps
Peak flow	760	L/s	17.35	mgd	12,048	gpm	26.84 fps
Peak hourly flow	760	L/s	17.35	mgd	12,048	gpm	26.84 fps
Velocity at Ave. Flow	0.83	m/s	2.71	fps			
Static Head	4.00	m	13.12	ft	5.7	psi	
Pipe area	0.22	m2	2.32	ft2			
Pipe diameter	900	mm	35.4	inches			
Velocity at peak daily flow	3.53	m/s	11.58	fps			
Friction factor, f	0.022						
Manning's roughness coefficient "	0.013						
Length of pipe	4,000	m	13,120	ft			
Friction head loss at ave. flow	3.37	m	11.05	ft.			
Minor losses at ave. flow	0.51	m	1.66	ft.			
Total dynamic head at Ave. flow	7.87	m	25.83	ft	11.2	psi	
Friction head loss at max.. flow	61.56	m	201.92	ft.			
Minor losses at max. flow	9.23	m	30.29	ft.			
Total dynamic head at max. flow	74.80	m	245.33	ft	106.2	psi	
Number of Pumps	4						
Duty pumps	3						
Overall efficiency	75%						
Flow each	253.33	L/s	5.78	mgd	4,016	gpm	
Power	26.07	kW	35	Hp			
Commercial motor size	37.30	kW	50	Hp			
Total connected power	111.90	kW	150	Hp			
Pump station dimensions (based on arbitrary elevations)							
High water elevation	5.00	m					
Low water elevation	3.00	m					
Discharge elevation	7.00	m					
Bottom elevation	2.30	m					
Freeboard	2	m					
Width	6	m					
Length	6	m					
Depth	4.70	m					
Estimated Concrete volume	137	m^3	180	cu. yards.			
Slab & cover	98	m^3	128	cu. yards.			
Walls	39	m^3	52	cu. yards.			
Effective wet well volume	72.00	m^3	19,022	gallons			
Design Population	155300						
Peaking factor	1.85						

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ENVIROSOFT-ENGINEERING & SCIENCE INC.

Project Name : Kotte Capital City
Location : Sri Lanka

By: EFA

Headworks Design

Average daily flow	26,400 M^3/day	6.97	MGD	4,844
Peak daily flow	33,000 M^3/day	8.72	MGD	6,055
Peak hourly flow	52,800 M^3/day	13.95	MGD	9,687
Peak/average flow ratio	1.25			
Peak hourly/average flow ratio	2.00			

Bar - Screens

Mechanically Cleaned Screens		
Screen spacing	19.1 mm	0.75 inches
Number of channels	1	
By-pass channel	1	
Dimensions		
Depth to width ratio at ave. flow	1.33	
Depth of water at ave. flow	0.74 m	2.41 ft.
Width	0.55 m	1.82 ft.
Screen bar thickness	9.53 mm	0.375 inches
Number of bars	18	
Channel area at average flow	0.407 m2	4.38 ft. 2
Channel area at peak flow	0.611 m2	
Approach velocity at ave. flow	0.750 m/s	2.46 ft./s
Approach velocity at peak hourly flow	1 m/s	3.28 ft./s
Depth of water at peak flow	1.10 m	3.62 ft.
Channel width	0.55 m	1.82 ft.
Head Loss at average flow		
$h_L = ß\ (w/b)^{1.3333}\ h_v \sin a$		
ß = a bar shape factor	2.42	
w = maximum cross-sectional area widt	0.010 m	0.374 inches
b = minimum clear spacing of the bars	0.0191 m	0.752 inches
Velocity of flow prior to screens	0.407 m/s	1.34 ft./s
Velocity throught the screens	0.799 m/s	2.62 ft./s
h_v = velocity head of flow approaching the b	0.034 m	0.11 ft.
a = angle of the rack with the horizontal	60	
Head loss at ave. flow	0.028 m	0.09 ft.
Velocity of flow prior to screens	1.000 m/s	3.28 ft./s
Velocity throught the screens	1.449 m/s	4.75 ft./s
h_v = velocity head of flow approaching the b	0.080 m/s	0.26 ft./s
Head loss at maximum flow	0.066 m	0.22 ft.

Grit Removal System

Process Type : Spiral Flow

Detention time at maximum flowrate	3.00 min.	
Detention time at average flowrate	6.00 min.	
Dimensions		
Diameter	4.27 m	14.00 ft

ANNEX 2

SEWAGE COLLECTION SYSTEM PRELIMINAY DESIGN CALCULATIONS

Envirosoft-Engineering & Scicne Inc.

Pumping Station Program

Project: Kotte U.C. Sewer System
Date: 1/28/97
By: EFA

PIPING & PUMP STATION _ Lift Sta. 1

Average daily flow	4.8	L/s	0.11	mgd	76	gpm
Peak daily flow	7.2	L/s	0.16	mgd	114	gpm
Peak hourly flow	18	L/s	0.41	mgd	285	gpm
Veocity at Ave. Flow	1.10	m/s	3.60	fps		
Static Head	25	m	82.00	ft	35.5	psi
Pipe area	0.0044	m2	0.05	ft2		
Pipe diameter	75	mm	2.9	inches		
Veocity at peak daily flow	1.65	m/s	5.40	fps		
Veocity at peak hourly flow	4.12	m/s	13.48	fps		
Friction factor, f	0.050					
Manning's roughness coefficient "n"	0.013					
Length of pipe	180	m	590	ft		
Friction head loss at ave. flow	7.39	m	24.23	ft.		
Minor losses at ave. flow	1.11	m	3.63	ft.		
Total dynamic head at Ave. flow	33.49	m	109.86	ft	47.6	psi
Friction head loss at max.. flow	16.62	m	54.51	ft.		
Minor losses at max. flow	2.49	m	8.18	ft.		
Total dynamic head at max. flow	44.11	m	144.69	ft	62.6	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	4.80	L/s	0.11	mgd	76	gpm
Power	2.25	kW	3	Hp		
Commercial motor size	3.73	kW	5	Hp		
Total connected power	3.73	kW	5	Hp		

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PIPING & PUMP STATION _ Lift Sta. 2

Average daily flow	56.2	L/s	1.28	mgd	891	gpm
Peak daily flow	84.3	L/s	1.92	mgd	1,336	gpm
Peak hourly flow	157	L/s	3.58	mgd	2,489	gpm
Veocity at Ave. Flow	1.13	m/s	3.70	fps		
Static Head	8	m	26.24	ft	11.4	psi
Pipe area	0.0499	m2	0.54	ft2		
Pipe diameter	252	mm	9.9	inches		
Veocity at peak daily flow	1.69	m/s	5.55	fps		
Veocity at peak hourly flow	3.15	m/s	10.32	fps		
Friction factor, f	0.033					
Manning's roughness coefficient "n"	0.013					
Length of pipe	400	m	1,312	ft		
Friction head loss at ave. flow	3.43	m	11.24	ft.		
Minor losses at ave. flow	0.51	m	1.69	ft.		
Total dynamic head at Ave. flow	11.94	m	39.16	ft	17.0	psi
Friction head loss at max.. flow	7.71	m	25.29	ft.		
Minor losses at max. flow	1.16	m	3.79	ft.		
Total dynamic head at max. flow	16.87	m	55.32	ft	23.9	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	28.10	L/s	0.64	mgd	445	gpm
Power	4.70	kW	6	Hp		
Commercial motor size	5.60	kW	7.5	Hp		
Total connected power	11.19	kW	15	Hp		

PIPING & PUMP STATION _ Lift Sta. 3

Average daily flow	12.8	L/s	0.29	mgd	203	gpm
Peak daily flow	19.2	L/s	0.44	mgd	304	gpm
Peak hourly flow	44	L/s	1.00	mgd	697	gpm
Veocity at Ave. Flow	1.07	m/s	3.50	fps		
Static Head	6	m	19.68	ft	8.5	psi
Pipe area	0.0120	m2	0.13	ft2		
Pipe diameter	124	mm	4.9	inches		
Veocity at peak daily flow	1.60	m/s	5.25	fps		
Veocity at peak hourly flow	3.67	m/s	12.01	fps		
Friction factor, f	0.042					
Manning's roughness coefficient "n"	0.013					
Length of pipe	400	m	1,312	ft		
Friction head loss at ave. flow	7.92	m	25.98	ft.		
Minor losses at ave. flow	1.19	m	3.90	ft.		
Total dynamic head at Ave. flow	15.11	m	49.55	ft	21.5	psi
Friction head loss at max.. flow	17.82	m	58.45	ft.		
Minor losses at max. flow	2.67	m	8.77	ft.		
Total dynamic head at max. flow	26.49	m	86.89	ft	37.6	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	12.80	L/s	0.29	mgd	203	gpm
Power	2.71	kW	4	Hp		
Commercial motor size	3.73	kW	5	Hp		
Total connected power	3.73	kW	5	Hp		

PIPING & PUMP STATION _ Lift Sta. 4

Average daily flow	131	L/s	2.99	mgd	2,077	gpm
Peak daily flow	196.5	L/s	4.49	mgd	3,115	gpm
Peak hourly flow	318	L/s	7.26	mgd	5,041	gpm
Veocity at Ave. Flow	1.36	m/s	4.45	fps		
Static Head	18	m	59.04	ft	25.6	psi
Pipe area	0.0966	m2	1.04	ft2		
Pipe diameter	351	mm	13.8	inches		
Veocity at peak daily flow	2.04	m/s	6.68	fps		
Veocity at peak hourly flow	3.29	m/s	10.79	fps		
Friction factor, f	0.030					
Manning's roughness coefficient "n"	0.013					
Length of pipe	1,700	m	5,576	ft		
Friction head loss at ave. flow	13.55	m	44.45	ft.		
Minor losses at ave. flow	2.03	m	6.67	ft.		
Total dynamic head at Ave. flow	33.58	m	110.16	ft	47.7	psi
Friction head loss at max.. flow	30.49	m	100.01	ft.		
Minor losses at max. flow	4.57	m	15.00	ft.		
Total dynamic head at max. flow	53.06	m	174.05	ft	75.3	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	65.50	L/s	1.50	mgd	1,038	gpm
Power	30.81	kW	41	Hp		
Commercial motor size	37.30	kW	50	Hp		
Total connected power	74.60	kW	100	Hp		

PIPING & PUMP STATION _ Lift Sta. 5

Average daily flow	11.5	L/s	0.26	mgd	182	gpm
Peak daily flow	17.25	L/s	0.39	mgd	273	gpm
Peak hourly flow	40	L/s	0.91	mgd	634	gpm
Veocity at Ave. Flow	0.95	m/s	3.10	fps		
Static Head	16	m	52.48	ft	22.7	psi
Pipe area	0.0122	m2	0.13	ft2		
Pipe diameter	125	mm	4.9	inches		
Veocity at peak daily flow	1.42	m/s	4.65	fps		
Veocity at peak hourly flow	3.29	m/s	10.77	fps		
Friction factor, f	0.042					
Manning's roughness coefficient "n"	0.013					
Length of pipe	350	m	1,148	ft		
Friction head loss at ave. flow	5.38	m	17.66	ft.		
Minor losses at ave. flow	0.81	m	2.65	ft.		
Total dynamic head at Ave. flow	22.19	m	72.79	ft	31.5	psi
Friction head loss at max.. flow	12.12	m	39.74	ft.		
Minor losses at max. flow	1.82	m	5.96	ft.		
Total dynamic head at max. flow	29.93	m	98.18	ft	42.5	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	11.50	L/s	0.26	mgd	182	gpm
Power	3.57	kW	5	Hp		
Commercial motor size	3.73	kW	5	Hp		
Total connected power	3.73	kW	5	Hp		

PIPING & PUMP STATION _ Lift Sta. 6

Average daily flow	10.9	L/s	0.25	mgd	173	gpm
Peak daily flow	16.35	L/s	0.37	mgd	259	gpm
Peak hourly flow	42	L/s	0.96	mgd	666	gpm
Veocity at Ave. Flow	0.88	m/s	2.90	fps		
Static Head	16	m	52.48	ft	22.7	psi
Pipe area	0.0123	m2	0.13	ft2		
Pipe diameter	125	mm	4.9	inches		
Veocity at peak daily flow	1.33	m/s	4.35	fps		
Veocity at peak hourly flow	3.41	m/s	11.16	fps		
Friction factor, f	0.042					
Manning's roughness coefficient "n"	0.013					
Length of pipe	500	m	1,640	ft		
Friction head loss at ave. flow	6.67	m	21.89	ft.		
Minor losses at ave. flow	1.00	m	3.28	ft.		
Total dynamic head at Ave. flow	23.67	m	77.65	ft	33.6	psi
Friction head loss at max.. flow	15.02	m	49.25	ft.		
Minor losses at max. flow	2.25	m	7.39	ft.		
Total dynamic head at max. flow	33.27	m	109.12	ft	47.2	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	10.90	L/s	0.25	mgd	173	gpm
Power	3.61	kW	5	Hp		
Commercial motor size	3.73	kW	5	Hp		
Total connected power	3.73	kW	5	Hp		

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PIPING & PUMP STATION _ Lift Sta. 7

Average daily flow	11.5	L/s	0.26	mgd	182	gpm
Peak daily flow	17.25	L/s	0.39	mgd	273	gpm
Peak hourly flow	44	L/s	1.00	mgd	697	gpm
Veocity at Ave. Flow	0.95	m/s	3.10	fps		
Static Head	17	m	55.76	ft	24.1	psi
Pipe area	0.0122	m2	0.13	ft2		
Pipe diameter	125	mm	4.9	inches		
Veocity at peak daily flow	1.42	m/s	4.65	fps		
Veocity at peak hourly flow	3.62	m/s	11.84	fps		
Friction factor, f	0.042					
Manning's roughness coefficient "n"	0.013					
Length of pipe	400	m	1,312	ft		
Friction head loss at ave. flow	6.15	m	20.19	ft.		
Minor losses at ave. flow	0.92	m	3.03	ft.		
Total dynamic head at Ave. flow	24.08	m	78.97	ft	34.2	psi
Friction head loss at max.. flow	13.85	m	45.42	ft.		
Minor losses at max. flow	2.08	m	6.81	ft.		
Total dynamic head at max. flow	32.92	m	107.99	ft	46.7	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	11.50	L/s	0.26	mgd	182	gpm
Power	3.88	kW	5	Hp		
Commercial motor size	3.73	kW	5	Hp		
Total connected power	3.73	kW	5	Hp		

PIPING & PUMP STATION _ Lift Sta. 8

Average daily flow	27.1	L/s	0.62	mgd	430	gpm
Peak daily flow	40.65	L/s	0.93	mgd	644	gpm
Peak hourly flow	92	L/s	2.10	mgd	1,458	gpm
Veocity at Ave. Flow	0.85	m/s	2.80	fps		
Static Head	17	m	55.76	ft	24.1	psi
Pipe area	0.0318	m2	0.34	ft2		
Pipe diameter	201	mm	7.9	inches		
Veocity at peak daily flow	1.28	m/s	4.20	fps		
Veocity at peak hourly flow	2.90	m/s	9.49	fps		
Friction factor, f	0.036					
Manning's roughness coefficient "n"	0.013					
Length of pipe	300	m	984	ft		
Friction head loss at ave. flow	1.99	m	6.52	ft.		
Minor losses at ave. flow	0.30	m	0.98	ft.		
Total dynamic head at Ave. flow	19.29	m	63.26	ft	27.4	psi
Friction head loss at max.. flow	4.47	m	14.67	ft.		
Minor losses at max. flow	0.67	m	2.20	ft.		
Total dynamic head at max. flow	22.14	m	72.63	ft	31.4	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	13.55	L/s	0.31	mgd	215	gpm
Power	3.66	kW	5	Hp		
Commercial motor size	3.73	kW	5	Hp		
Total connected power	7.46	kW	10	Hp		

PIPING & PUMP STATION _ Lift Sta. 9

Average daily flow	53.3	L/s	1.22	mgd	845	gpm
Peak daily flow	79.95	L/s	1.83	mgd	1,267	gpm
Peak hourly flow	165	L/s	3.77	mgd	2,616	gpm
Veocity at Ave. Flow	1.10	m/s	3.60	fps		
Static Head	40	m	131.20	ft	56.8	psi
Pipe area	0.0486	m2	0.52	ft2		
Pipe diameter	249	mm	9.8	inches		
Veocity at peak daily flow	1.65	m/s	5.40	fps		
Veocity at peak hourly flow	3.40	m/s	11.13	fps		
Friction factor, f	0.033					
Manning's roughness coefficient "n"	0.013					
Length of pipe	2,500	m	8,200	ft		
Friction head loss at ave. flow	20.62	m	67.63	ft.		
Minor losses at ave. flow	3.09	m	10.15	ft.		
Total dynamic head at Ave. flow	63.71	m	208.98	ft	90.5	psi
Friction head loss at max.. flow	46.40	m	152.18	ft.		
Minor losses at max. flow	6.96	m	22.83	ft.		
Total dynamic head at max. flow	93.36	m	306.21	ft	132.6	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	26.65	L/s	0.61	mgd	422	gpm
Power	23.78	kW	32	Hp		
Commercial motor size	37.30	kW	50	Hp		
Total connected power	74.60	kW	100	Hp		

PIPING & PUMP STATION _ Lift Sta. 10

Average daily flow	6.7	L/s	0.15	mgd	106	gpm
Peak daily flow	10.05	L/s	0.23	mgd	159	gpm
Peak hourly flow	27	L/s	0.62	mgd	428	gpm
Veocity at Ave. Flow	0.85	m/s	2.80	fps		
Static Head	10	m	32.80	ft	14.2	psi
Pipe area	0.0079	m2	0.08	ft2		
Pipe diameter	100	mm	3.9	inches		
Veocity at peak daily flow	1.28	m/s	4.20	fps		
Veocity at peak hourly flow	3.44	m/s	11.27	fps		
Friction factor, f	0.045					
Manning's roughness coefficient "n"	0.013					
Length of pipe	500	m	1,640	ft		
Friction head loss at ave. flow	8.41	m	27.57	ft.		
Minor losses at ave. flow	1.26	m	4.14	ft.		
Total dynamic head at Ave. flow	19.67	m	64.51	ft	27.9	psi
Friction head loss at max.. flow	18.91	m	62.03	ft.		
Minor losses at max. flow	2.84	m	9.31	ft.		
Total dynamic head at max. flow	31.75	m	104.14	ft	45.1	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	6.70	L/s	0.15	mgd	106	gpm
Power	1.85	kW	2	Hp		
Commercial motor size	1.87	kW	2.5	Hp		
Total connected power	1.87	kW	2.5	Hp		

PIPING & PUMP STATION _ Lift Sta. 11

Average daily flow	42	L/s	0.96	mgd	666	gpm
Peak daily flow	63	L/s	1.44	mgd	999	gpm
Peak hourly flow	135	L/s	3.08	mgd	2,140	gpm
Veocity at Ave. Flow	0.85	m/s	2.80	fps		
Static Head	35	m	114.80	ft	49.7	psi
Pipe area	0.0492	m2	0.53	ft2		
Pipe diameter	250	mm	9.9	inches		
Veocity at peak daily flow	1.28	m/s	4.20	fps		
Veocity at peak hourly flow	2.74	m/s	8.99	fps		
Friction factor, f	0.033					
Manning's roughness coefficient "n"	0.013					
Length of pipe	450	m	1,476	ft		
Friction head loss at ave. flow	2.23	m	7.30	ft.		
Minor losses at ave. flow	0.33	m	1.10	ft.		
Total dynamic head at Ave. flow	37.56	m	123.20	ft	53.3	psi
Friction head loss at max.. flow	5.01	m	16.43	ft.		
Minor losses at max. flow	0.75	m	2.46	ft.		
Total dynamic head at max. flow	40.76	m	133.69	ft	57.9	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	21.00	L/s	0.48	mgd	333	gpm
Power	11.05	kW	15	Hp		
Commercial motor size	11.19	kW	15	Hp		
Total connected power	22.38	kW	30	Hp		

PIPING & PUMP STATION _ Lift Sta. 12

Average daily flow	28.3	L/s	0.65	mgd	449	gpm
Peak daily flow	42.45	L/s	0.97	mgd	673	gpm
Peak hourly flow	96	L/s	2.19	mgd	1,522	gpm
Veocity at Ave. Flow	0.90	m/s	2.95	fps		
Static Head	15	m	49.20	ft	21.3	psi
Pipe area	0.0315	m2	0.34	ft2		
Pipe diameter	200	mm	7.9	inches		
Veocity at peak daily flow	1.35	m/s	4.43	fps		
Veocity at peak hourly flow	3.05	m/s	9.99	fps		
Friction factor, f	0.036					
Manning's roughness coefficient "n"	0.013					
Length of pipe	1,200	m	3,936	ft		
Friction head loss at ave. flow	8.88	m	29.11	ft.		
Minor losses at ave. flow	1.33	m	4.37	ft.		
Total dynamic head at Ave. flow	25.21	m	82.68	ft	35.8	psi
Friction head loss at max.. flow	19.97	m	65.50	ft.		
Minor losses at max. flow	3.00	m	9.83	ft.		
Total dynamic head at max. flow	37.96	m	124.53	ft	53.9	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	14.15	L/s	0.32	mgd	224	gpm
Power	4.99	kW	7	Hp		
Commercial motor size	7.46	kW	10	Hp		
Total connected power	14.92	kW	20	Hp		

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PIPING & PUMP STATION _ Lift Sta. 13

Average daily flow	126.5	L/s	2.89	mgd	2,005	gpm
Peak daily flow	189.75	L/s	4.33	mgd	3,008	gpm
Peak hourly flow	339	L/s	7.74	mgd	5,374	gpm
Veocity at Ave. Flow	1.01	m/s	3.30	fps		
Static Head	10	m	32.80	ft	14.2	psi
Pipe area	0.1259	m2	1.35	ft2		
Pipe diameter	400	mm	15.8	inches		
Veocity at peak daily flow	1.51	m/s	4.95	fps		
Veocity at peak hourly flow	2.70	m/s	8.83	fps		
Friction factor, f	0.029					
Manning's roughness coefficient "n"	0.013					
Length of pipe	650	m	2,132	ft		
Friction head loss at ave. flow	2.39	m	7.84	ft.		
Minor losses at ave. flow	0.36	m	1.18	ft.		
Total dynamic head at Ave. flow	12.75	m	41.81	ft	18.1	psi
Friction head loss at max.. flow	5.38	m	17.64	ft.		
Minor losses at max. flow	0.81	m	2.65	ft.		
Total dynamic head at max. flow	16.18	m	53.08	ft	23.0	psi
Number of Pumps	3					
Duty pumps	2					
Overall efficiency	70%					
Flow each	63.25	L/s	1.44	mgd	1,003	gpm
Power	11.29	kW	15	Hp		
Commercial motor size	11.19	kW	15	Hp		
Total connected power	22.38	kW	30	Hp		

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PIPING & PUMP STATION _ Lift Sta. 14

Average daily flow	10	L/s	0.23	mgd	159	gpm
Peak daily flow	15	L/s	0.34	mgd	238	gpm
Peak hourly flow	38	L/s	0.87	mgd	602	gpm
Veocity at Ave. Flow	0.82	m/s	2.70	fps		
Static Head	8	m	26.24	ft	11.4	psi
Pipe area	0.0122	m2	0.13	ft2		
Pipe diameter	124	mm	4.9	inches		
Veocity at peak daily flow	1.23	m/s	4.05	fps		
Veocity at peak hourly flow	3.13	m/s	10.24	fps		
Friction factor, f	0.042					
Manning's roughness coefficient "n"	0.013					
Length of pipe	2	m	7	ft		
Friction head loss at ave. flow	0.02	m	0.08	ft.		
Minor losses at ave. flow	0.00	m	0.01	ft.		
Total dynamic head at Ave. flow	8.03	m	26.33	ft	11.4	psi
Friction head loss at max.. flow	0.05	m	0.17	ft.		
Minor losses at max. flow	0.01	m	0.03	ft.		
Total dynamic head at max. flow	8.06	m	26.44	ft	11.4	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	10.00	L/s	0.23	mgd	159	gpm
Power	1.12	kW	2	Hp		
Commercial motor size	1.87	kW	2.5	Hp		
Total connected power	1.87	kW	2.5	Hp		

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PIPING & PUMP STATION _ Lift Sta. 15

Average daily flow	87	L/s	1.99	mgd	1,379	gpm
Peak daily flow	130.5	L/s	2.98	mgd	2,069	gpm
Peak hourly flow	248	L/s	5.66	mgd	3,931	gpm
Veocity at Ave. Flow	0.90	m/s	2.95	fps		
Static Head	20	m	65.60	ft	28.4	psi
Pipe area	0.0968	m2	1.04	ft2		
Pipe diameter	351	mm	13.8	inches		
Veocity at peak daily flow	1.35	m/s	4.43	fps		
Veocity at peak hourly flow	2.56	m/s	8.40	fps		
Friction factor, f	0.030					
Manning's roughness coefficient "n"	0.013					
Length of pipe	300	m	984	ft		
Friction head loss at ave. flow	1.05	m	3.44	ft.		
Minor losses at ave. flow	0.16	m	0.52	ft.		
Total dynamic head at Ave. flow	21.21	m	69.56	ft	30.1	psi
Friction head loss at max.. flow	2.36	m	7.75	ft.		
Minor losses at max. flow	0.35	m	1.16	ft.		
Total dynamic head at max. flow	22.72	m	74.51	ft	32.3	psi
Number of Pumps	4					
Duty pumps	3					
Overall efficiency	70%					
Flow each	29.00	L/s	0.66	mgd	460	gpm
Power	8.61	kW	12	Hp		
Commercial motor size	11.19	kW	15	Hp		
Total connected power	33.57	kW	45	Hp		

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PIPING & PUMP STATION _ Lift Sta. 16

Average daily flow	15.3	L/s	0.35	mgd	243	gpm
Peak daily flow	22.95	L/s	0.52	mgd	364	gpm
Peak hourly flow	56	L/s	1.28	mgd	888	gpm
Veocity at Ave. Flow	0.87	m/s	2.85	fps		
Static Head	15	m	49.20	ft	21.3	psi
Pipe area	0.0176	m2	0.19	ft2		
Pipe diameter	150	mm	5.9	inches		
Veocity at peak daily flow	1.30	m/s	4.28	fps		
Veocity at peak hourly flow	3.18	m/s	10.42	fps		
Friction factor, f	0.040					
Manning's roughness coefficient "n"	0.013					
Length of pipe	300	m	984	ft		
Friction head loss at ave. flow	3.05	m	10.00	ft.		
Minor losses at ave. flow	0.46	m	1.50	ft.		
Total dynamic head at Ave. flow	18.51	m	60.70	ft	26.3	psi
Friction head loss at max.. flow	6.86	m	22.50	ft.		
Minor losses at max. flow	1.03	m	3.38	ft.		
Total dynamic head at max. flow	22.89	m	75.08	ft	32.5	psi
Number of Pumps	2					
Duty pumps	1					
Overall efficiency	70%					
Flow each	15.30	L/s	0.35	mgd	243	gpm
Power	3.97	kW	5	Hp		
Commercial motor size	4.85	kW	6.5	Hp		
Total connected power	4.85	kW	6.5	Hp		

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PIPING & PUMP STATION _ Lift Sta. 17

Average daily flow	110	L/s	2.51	mgd	1,744	gpm
Peak daily flow	165	L/s	3.77	mgd	2,616	gpm
Peak hourly flow	301	L/s	6.87	mgd	4,771	gpm
Veocity at Ave. Flow	0.87	m/s	2.85	fps		
Static Head	16	m	52.48	ft	22.7	psi
Pipe area	0.1267	m2	1.36	ft2		
Pipe diameter	402	mm	15.8	inches		
Veocity at peak daily flow	1.30	m/s	4.28	fps		
Veocity at peak hourly flow	2.38	m/s	7.79	fps		
Friction factor, f	0.029					
Manning's roughness coefficient "n"	0.013					
Length of pipe	500	m	1,640	ft		
Friction head loss at ave. flow	1.36	m	4.48	ft.		
Minor losses at ave. flow	0.20	m	0.67	ft.		
Total dynamic head at Ave. flow	17.57	m	57.63	ft	24.9	psi
Friction head loss at max.. flow	3.07	m	10.07	ft.		
Minor losses at max. flow	0.46	m	1.51	ft.		
Total dynamic head at max. flow	19.53	m	64.06	ft	27.7	psi
Number of Pumps	4					
Duty pumps	3					
Overall efficiency	70%					
Flow each	36.67	L/s	0.84	mgd	581	gpm
Power	9.02	kW	12	Hp		
Commercial motor size	11.19	kW	15	Hp		
Total connected power	33.57	kW	45	Hp		

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Gravity Pipe

NO.	Area (hac)	Pipe Length (m)										Total	MH	No. LS
		200 mm	250 mm	300 mm	400 mm	450 mm	600mm	700 mm	900 mm	1000 mm	1100 mm			
1	44	1,300	800	700								2,800	28	1
2	72	2,500	200	300								3,000	30	1
3	116	3,100	600		250	500	500					4,950	50	1
4	188	5,000	500		550		600					6,650	67	1
5	110	5,000	700	300								6,000	60	2
6	138	3,400	700	250					900	520		5,770	58	2
7	114	3,700	1,800	650	900							7,050	71	1
8	155	5,000	1,300	850	260							7,410	74	2
9	122	5,000	840	350	650			700				7,540	75	2
10	88	2,400	700	250						1,300	650	5,300	53	1
11	218	7,700	650	800	1,350		400	100				11,000	110	3
12	103	3,500	800	800					550	350		6,000	60	
Total	1,468	47,600	9,590	5,250	3,960	500	1,500	800	1,450	2,170	650	73,470	735	18

Force Main

No.	Area	Diameter (mm)									
	(hac)	75	100	125	150	200	250	300	350	400	Total
1	44	180									180
2	72						400				400
3	116			400							400
4	188								1700		0
5	110			750							750
6	138			500		300					800
7	114						2500				2500
8	155		500				450				950
9	122					1200				650	1200
10	88										0
11	218			2	300				300		302
12	103									500	0
Total	1468	0	500	1652	300	1500	3350	0	2000	1150	7302

Existing Flows

				Current					
Area		Popu. Density	Design popu.	q	Popu.	Flow Rate	Kh	Flow Rate	
#	(Hac)	(p/hac)	Density (p/hac)	(l/d-p)		Q (m^3/d)		Qh(m^3/h)	Qs (l/s)
1	44	82	91	160	3983	677	3.3	94	26.1
2	72	82	91	160	6518	1108	3.1	145	40.2
3	116	110	121	160	14087	2395	2.8	280	77.8
4	188	68	75	160	14114	2399	2.8	280	77.9
5	110	54	60	160	6558	1115	3.1	146	40.4
6	138	82	91	160	12493	2124	2.9	253	70.3
7	114	110	121	160	13844	2354	2.8	276	76.6
8	155	68	75	160	11636	1978	2.9	238	66.1
9	122	54	60	160	7273	1236	3.1	159	44.2
10	88	110	121	160	10687	1817	2.9	221	61.5
11	218	120	132	160	28881	4910	2.5	510	141.7
12	103	82	91	160	9324	1585	3.0	197	54.8
Total	1468				139398	23698		2799.698	777.7
					Control Value				
					139300				

Future Flows

		1997			2000			2010			2020		
		Flow rate			Flow rate			Flow rate			Flow rate		
Area		Ave. Daily	Peak Time		Ave. Daily	Peak Time		Ave. Daily	Peak Time		Ave. Daily	Peak Time	
#	(Hac)	Qd	Qh	Q	Qd	Qh	Q	Qd	Qh	Q	Qd	Qh	Q
		(m^3/d)	(m^3/h)	(l/s)	(m^3/d)	(m^3/h)	(l/s)	(m^3/d)	(m^3/h)	(l/s)	(m^3/d)	(m^3/h)	(l/s)
1	44	677	94	26.1	756	105	29	1016	141	39	1361	189	52
2	72	1108	145	40.3	1237	162	45	1663	218	60	2228	292	81
3	116	2395	280	77.8	2673	313	87	3595	420	117	4815	563	156
4	188	2399	280	77.8	2678	313	87	3601	420	117	4823	563	156
5	110	1115	146	40.6	1245	163	45	1674	219	61	2242	294	82
6	138	2124	253	70.3	2371	282	78	3188	380	105	4270	509	141
7	114	2354	276	76.7	2628	308	86	3533	414	115	4733	555	154
8	155	1978	238	66.1	2208	266	74	2969	357	99	3977	479	133
9	122	1236	159	44.2	1380	177	49	1855	239	66	2485	320	89
10	88	1817	221	61.4	2028	247	69	2727	332	92	3653	444	123
11	218	4910	510	141.7	5481	569	158	7369	765	213	9872	1025	285
12	103	1585	197	54.7	1769	220	61	2379	296	82	3187	396	110
Total	1468	23698	2799	777.5	26453.09	3124.4	867.9	35568.5	4201	1167	47645.932	5627.5	1563.2

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ANNEX 3

SCOPES OF WORK FOR COMPLETION OF THE WASTEWATER MANAGEMENT MASTER PLAN FOR KOTTE U.C.

WATER QUALITY MONITORING AND SAMPLING SCOPE OF WORK

The objective of this study is to gather site-specific data that is relevant to the Feasibility Study for the Management of Wastewater Discharges in Srijayawardenepura Kotte. The data obtained from the sampling program will be used to assess the "no action alternative" and for the development of waste management scenarios. Another objective of the study is to identify permanent monitoring stations to track long-term pollutant loading to the receiving bodies of water derived from Srijayawardenepura Kotte. The stations will be used to measure the improvements or deterioration of water quality of the river in the study area. The permanent stations will be recommended as a result of the initial sampling events. The duration of the sampling programs are :

Initial Phase: Four weeks

Long-term: Ten years beyond the initial Monitoring and Sampling Program (not included in the budget)

Types of Samples. Dry-weather grab water quality samples and instantaneous flow measurements.

Sampling Locations. To be determined based on field reconnaissance.

Frequency. Sample collection must be done strictly during dry weather (absence of significant rainfall) or 24 hours after a significant rainfall event exceeding 10 mm (0.4 in.). Each station will be sampled four times (once per week).

Monitoring Parameters. Three sets of monitoring parameters will be performed:

Set 1 - Conventional Water Quality Parameters. This set of parameters include typical water quality parameters.

Five-day biochemical oxygen demand, BOD_5
Chemical oxygen demand, COD
Total suspended solids, TSS
*Temperature, T ^oC **
*pH **
*Dissolved oxygen, DO **
Fecal coliforms

* Field method

Set 2 - Nutrients and Indicator Metals. This set of water quality parameters includes nutrients and indicator heavy metals. Total and hexavalent chromium and lead are selected as indicator heavy metals because these are typical metals found in industrial wastewaters.

Total phosphorus, Tot.- P
Orthophosphate, PO_4
Polyphosphates,
Total kjeldahl nitrogen, TKN
Nitrate
Nitrite
Total Chromium
Hexavalent chromium
Lead

Set 3 - Physical Chemical Parameters (1 sample from Station 1)

Flow Measurements. Using the velocity-area method, the flowrate at each station will be determined (if possible) by multiplying the velocity of flow (m/s) by the cross-sectional area (m^2) through which the flow is occurring. The method to determine velocity uses an electronic velocity meter. The area is determined by direct measurement in the field at the time that the velocity measurements are taken. Velocity meter measurements will be done using the two-point method for depths of 0.5 meters and higher and the one-point method for depths smaller than 0.5 meters. In the two-point method the velocity is observed at 0.2 and 0.8 of depth and the average of these two figures is taken to represent the average velocity in the vertical section. In the one-point method, the meter is held at 0.6 depth of the stream and the resulting velocity is taken as the average velocity in the vertical section. The streams and canals can be divided into a number of vertical sections and the average velocity in each section is approximately determined by this method. In the multiple point method, sufficient readings are taken so that the velocity contours are developed. The calculated flow through each section is summed to obtain the total flow. The flow will be calculated using a velocity measurement technique.

COMPREHENSIVE COMMUNITY SURVEY SCOPE

The existing socio-economic information needed for the master plan is incomplete. An official census has not been conducted since 1981 and available data is derived from projected updates and other estimates by the Kotte Urban Council. Therefore, it is important that a statistically-significant community survey be conducted for verification and enhancement of the existing socio-economic database. The community survey would include door-to-door visits to fill a questionnaire. Earlier this year, a similar survey was conducted by the Kotte UC in 100 homes. This time, the survey should be conducted by the UDA and cover at least 5 percent of the population. The sample population should be representative of the total population. The response of the questionnaire will evaluated by the UDA and used to describe the existing conditions regarding population density, existing water and wastewater services, level of satisfaction with existing services, willingness to pay for better water supply and sewage collection services, annual income, utilities expenses, etc. A preliminary questionnaire is provided below.

Preliminary Questionnaire

- Name
- Address
- Subarea location
- General Location Code
- Years living there
- Age of dwelling
- Number of people
- Number of Adults over 18
- Number of children under 12
- Type of system used for wastewater & excreta disposal

    Sewer discharge

    Latrine

    Onsite system A, B, C, D, or F type

    Other

    None

- If On-Site, provide the location with regard to the street

    Front

    Back

    Sides

- Level of difficulty for connection to sewer

    High

    Medium

    Small

- Estimated depth to ground water

    Seasonal high

    Medium

    Low

- Estimated distance to the nearest water course
- Type of soil
- Annual household income
- Monthly income
- Number of persons generating income
- Monthly water bill
- Monthly bill for other utilities (electric, gas, telephone, garbage, etc.)
- Do they consider the use of the existing system a health hazard?
- Do they have problems with the existing system?
- How often does it have to be serviced?
- How much do they pay for service?
- Are they willing to pay for better service?
- Are they willing to pay for sewers?
- Would they willingly connect to the public sewer if it means an extra expense?
- How much are they willing to pay for a reliable water and sanitation system?

  Less than 100 ____, 100 ____, 250_____, or 350 _____ Rs per month.
- Has anyone been sick due to poor sanitation? Explain.
- Water supply source. Well ____ Piped ___ Other ____

ENVIRONMENTAL ASSESSMENT SCOPE OF WORK

To perform a thorough evaluation of the environmental conditions surrounding the Srijayawardenepura Kotte wastewater treatment plant, additional information will need to be collected at Sri Lankan agencies, universities, research centers, and private institutions. Elements of the environmental assessment will include, but not be limited to, evaluation of natural environment components such as threatened and endangered species, and socioeconomic conditions in the project area. Additionally, the level of compliance with pertinent environmental regulations will also be evaluated.

After all pertinent data are collected, a detailed evaluation will be performed to determine the beneficial and adverse environmental impacts caused by the WWTP construction and operation. Once the impacts have been evaluated, impact mitigation measures if necessary, will be recommended. The report outline is as follows:

ENVIRONMENTAL IMPACT ASSESSMENT FOR WASTEWATER TREATMENT FACILITIES AND SEWER COLLECTION SYSTEM

1.0 INTRODUCTION

2.0 ENVIRONMENTAL SETTING OF THE STUDY AREA

2.1 Existing Environmental Conditions

Location and Local Geography

Climate

Hydrology

Socio-economic Aspects

Infrastructure and Basic Services

Surface Water and Groundwater

Biological Characteristics, flora and fauna
Endangered species
Geological Characteristics
Seismic Risks, and
Flooding

2.2 Potential Plant Sites for Wastewater Treatment Facilities

3.0 DESCRIPTION OF THE SELECTED TREATMENT ALTERNATIVES

4.0 ENVIRONMENTAL IMPACT OF THE NO-ACTION ALTERNATIVES

4.1 General
4.2 Impact on Receiving Stream Water Quality
4.3 Impact on Potential Beneficial Uses of Waters
4.4 Impact on Biological Characteristics
4.5 Socio-economic Impact

5.0 ENVIRONMENTAL IMPACT OF SELECTED ALTERNATIVES

5.1 Identification of Potential Impact Area
5.2 Method of Evaluation of Environmental Impact
5.3 Evaluation of Impact for Wastewater Treatment Systems
Impact during Operation and Maintenance
Impact during Construction
5.4 Evaluation of Impact for Wastewater Treatment Systems
Impact during Operation and Maintenance
Impact during Construction
5.5 Summary of Impact Evaluation

6.0 MITIGATION MEASURES OF NEGATIVE IMPACTS

Mitigation Measures of Negative Impacts during Operation and Maintenance

Mitigation Measures of Negative Impacts during Construction

7.0 CONCLUSIONS

8.0 REFERENCES

PLANT SITING SCOPE OF WORK

The objective of this task is to evaluate several potential sites for location of the wastewater treatment plant for the Srijayawardenepura Kotte area. The study should identify sites in three categories: (1) Available sites with an area of 70 hectares or more – for use as facultative lagoons, (2) Available sites with about 30 to 40 hectares -- for use with a combination of biological process and constructed wetlands, and (3) Available sites with about 2 to 5 hectares – for possible use for a mechanical plant or preliminary treatment for disposal at the Southern Outfall.

The UDA will have the main responsibility for evaluating the sites. Data about the potential sites will be summarized in tables that include the following information:

Site Location
Estimated available area
General geology
Hydrology
Predominant wind direction
Proximity to population centers
Environmental impacts
Availability of utilities in the proximity of the site (water, telecommunications, and electricity)
Land acquisition requirements and availability
Transportation access
Public acceptance potential

The sites will be identified with a site number, and plotted in a general map with scale of 1:10,000

PUBLIC PARTICIPATION SCOPE OF WORK

A public participation program is a systematic mechanism of communication that assures an appropriate involvement of all parties that could affect or be affected by the "Srijayawardenepura Kotte Wastewater Treatment Plant Project (SKWWTP)". A thorough approach to a public participation program is recommended in this section.

To meet the goals and objectives of any community participation plan, it is essential to develop a strategy that identifies the program components to successfully accomplish the goals and objectives that are predetermined. This strategy identifies the Public Participation Program (PPP) purpose and objectives, describes the PPP process, outlines the scope of work, and shows the general approach to be followed in identifying those facilities project issues that will be communicated. In addition, it presents the general criteria to identify and to assess target publics and communication objectives, and provides the public participation measures to be considered.

The recommended public participation program includes two phases: 1) design and implementation; and 2) operation and review.

Phase 1 includes the design and implementation of the PPP. Plan components will be addressed in this phase in such a way that the results of an action-oriented plan are capable of being adjusted because of the dynamic nature of the public involvement process. Each step in the process builds upon the results and information gathered in the previous step.

The process of the PPP will include the following components:

- Development of a Situation Summary and Problem Statement.
- Identification of Target Population and Potential Public Issues
- Identification of Communication Objectives

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- Development of the Communication Program
- Communication Program Evaluation and Program Adjustments

Anticipated community elements that might be participating in the PPP include: the general public within the project area of influence; community leaders; elected officials; federal, state and local agencies representatives, non-governmental organizations, and academic institutions.

Phase 2 consists in operating and reviewing the PPP throughout the several steps of the SKWWTP project.

DETAILED ECONOMIC AND FINANCIAL PLAN SCOPE

The objective of the financial plan is to establish a financial strategy which will address the following:

1. Capital and operating cost estimates;
2. Funding mechanisms;
3. Rate structures; and
4. Cash flow projections.

In essence, this task will outline the business plan for the construction and operation of collection, transport, treatment, storage and disposal facilities. This task will result in a document presenting the Financial Plan.

Cost Estimates
Both capital and operating cost estimates will be developed for facilities and systems.

Funding Mechanisms
Funding Mechanisms will be identified and evaluated.

Rate Structures
Preliminary rate structures for the collection, transportation, storage, treatment, and disposal of various types of oil and solvents will be developed.

Cash Flow Projections
Preliminary pro-forma financial statements and cash flow projections will be developed.

PREQUALIFICATION PACKAGE SCOPE OF WORK

The objective of this scope of work is to develop a prequalifications package for potential bidders for a built operate and transfer (BOT) type contract. The objective is to prequalify a group of about five firms that have the experience in the design, construction, operation, maintenance and financing wastewater management infrastructure projects. The outline for the prequalifications package is as follows:

GLOSSARY

ABBREVIATIONS AND ACRONYMS BACKGROUND

GENERAL PROJECT DESCRIPTION

A. General

B. Project Schedule

SUBMITTAL

A. Submittal of a Deadline and Address

B. Number of Copies

C. Official Language

D. Interpretation

E. Rejection of Responses

F. Disclosure (Statement about liabilities of the owner and contractor)

G. Proposer's Information Meeting

REQUEST FOR PREQUALIFICATIONS

A. Detailed Response Requirements

B. Criteria for Prequalifying Most Qualified Proposers

C. Notification to Proposers

D. General Provisions

CONTRACT PRINCIPLES TO BE INCLUDED IN THE RQUEST FOR PROPOSAL

A. General Contract Principles

B. Contract Negotiations Approach

C. Relation to Bond Issue

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DEVELOPMENT OF A MUNICIPAL CODE FOR ONSITE SYSTEMS

SCOPE OF WORK

There is no piped sewage in the Sri Jayawardenepura Kotte area. All systems are on-site and include, among others:

- Open pits
- Latrines
- Water sealed latrines
- Seepage pits
- Septic tanks

Site-specific information about the on-site systems in not available, since no survey or inventory has been made for the area. In general, these systems have a poor design and lack a soil adsorption system. There are no local or national ordinances or codes specifying the proper design of onsite sanitation systems. Some homeowners discharge only the toilet water to the septic tank and the gray waters are discharged to the ground surface. In some instances, the septic tank outlet discharges to the ground surface or to a nearby body of water.

The purpose of this task is to develop an interim municipal code that establishes the guidelines for permitting onsite wastewater systems for new construction in the study area. The new municipal code must have the following components:

General Provisions
General Use Requirements
Soil Suitability Requirements for Onsite Disposal Systams
Wastewater Discharge Permit Application
Wastewater Discharge Permit Issuance Process
Reporting Requirements
Judicial Enforcement
Miscellaneous Provisions
Inspection Procedures
Maintenance Requirements
Fee Schedule

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MASTER PLAN OUTLINE

The master plan will incorporate the updated information generated in the Pre-Feasibility Study plus the new information gathered in the additional tasks that need to be performed. The preliminary outline of the integrated master plan is as follows:

1. EXECUTIVE SUMMARY
2. EXISTING SITUATION
    - Study area description
    - Population
    - Other socio-economic issues
    - Land use/zoning
    - Existing water system components (supply, treatment, distribution and storage)
        - Administrative and management structure (operational and commercial structure)
        - Accounting and financing structure
    - Water rates and fees
    - Diagnosis of the supply, distribution and storage system
        - Micro/macro metering
        - Operation and maintenance
    - Unaccounted for water analysis
    - Onsite systems diagnostic (types, effectiveness, problems)
    - Municipal (wastewater characterization)

Regulatory framework

Water quality

Environmental and public health

Public participation

Sustainable development

3. FUTURE SITUATION (SHORT-TERM AND LONG TERM)

Population

Other socio-economic issues

Land use/zoning

Local, State and Federal governmental structure

Water system

Administration and accounting

Line replacements and new lines

Micro/macro metering needs

Wastewater system (collection, treatment and disposal/reuse)

Municipal (flow and characterization)

Regulatory framework

Water quality criteria

Effluent reuse-zero discharge

Discharge scenarios

Combination of discharge/reuse scenarios

Environmental and public health

Public participation

Sustainable development

4. EVALUATION TECHNOLOGIES

Water supply, distribution, storage and conservation

Wastewater collection, treatment, and disposal/reuse

5. EVALUATION OF ALTERNATIVES

Water supply, distribution, storage and conservation

Wastewater collection, treatment, and disposal/reuse

6. RECOMMENDED PLAN

Water supply, distribution, storage and conservation

Wastewater collection, treatment, and disposal/reuse

7. OPERATION AND MAINTENANCE PLAN

Wastewater collection, treatment, and disposal/reuse

Recommended management and administrative structure

8. COMMUNITY PARTICIPATION

Water supply, distribution, storage and conservation

Wastewater collection, treatment, and disposal/reuse

9. ENVIRONMENTAL IMPACT

10. COST-BENEFIT ANALYSIS

11. COST RECOVERY OPTIONS (Fees, taxes and revenues)

12. PROJECT FINANCING

Capital investments

O&M Costs

Parameters and assumptions

Possible financing scenarios

Pro forma - cash flow analysis

Sensitivity analysis