JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIC OF KENYA

MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES

# THE STUDY ON INSTITUTIONAL IMPROVEMENT AND REHABILITATION OF WATER SUPPLY SYSTEMS FOR 10 LOCAL TOWNS IN THE REPUBLIC OF KENYA

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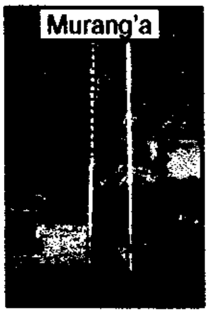
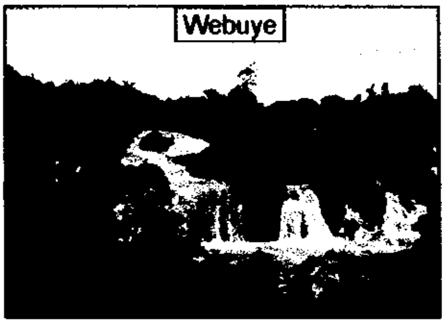
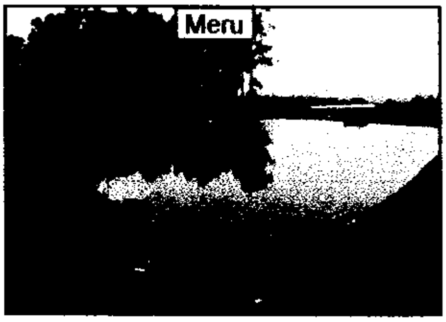
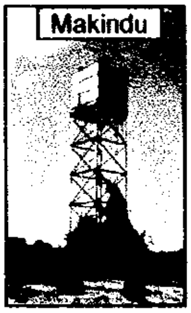
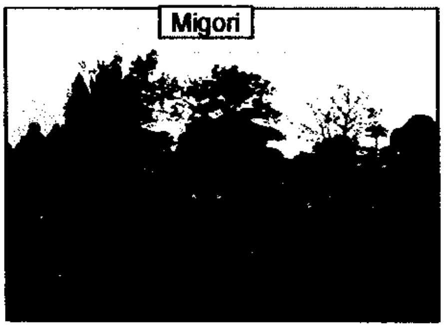


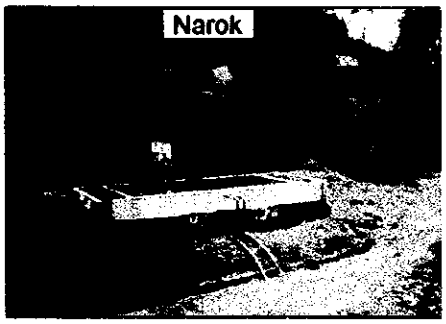



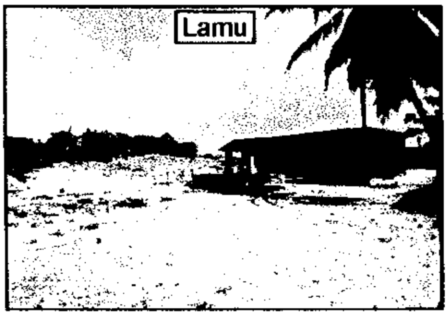



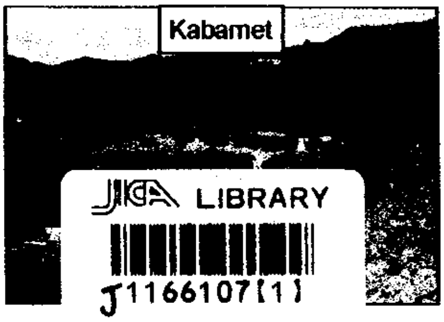



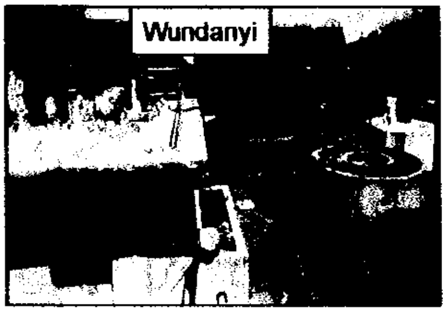







**FINAL REPORT**

**Volume 2I : Main Report (including Appendices) - Webuye Town**

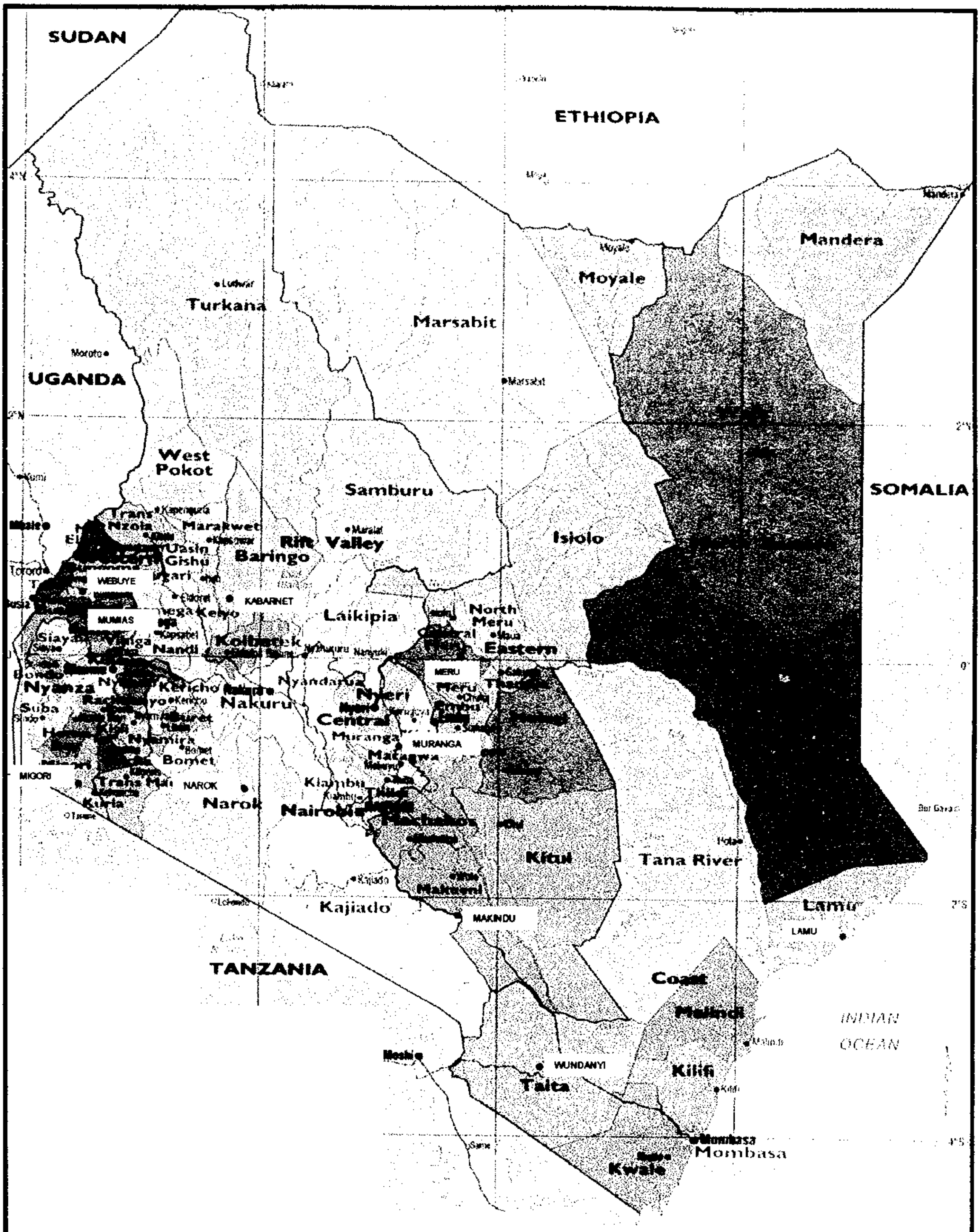
**FEBRUARY 2001**

Development Impact Consulting

Engineering and Utility Management Ltd.

Gibb Eastern Africa Ltd.

GIBB Eastern Africa
LAWGIBB Group Member




# TEN TOWNS WATER & SANITATION STUDY

## TOWNS LOCATION MAP

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# WEBUYE WATER SUPPLY

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## LIST OF ABBREVIATIONS

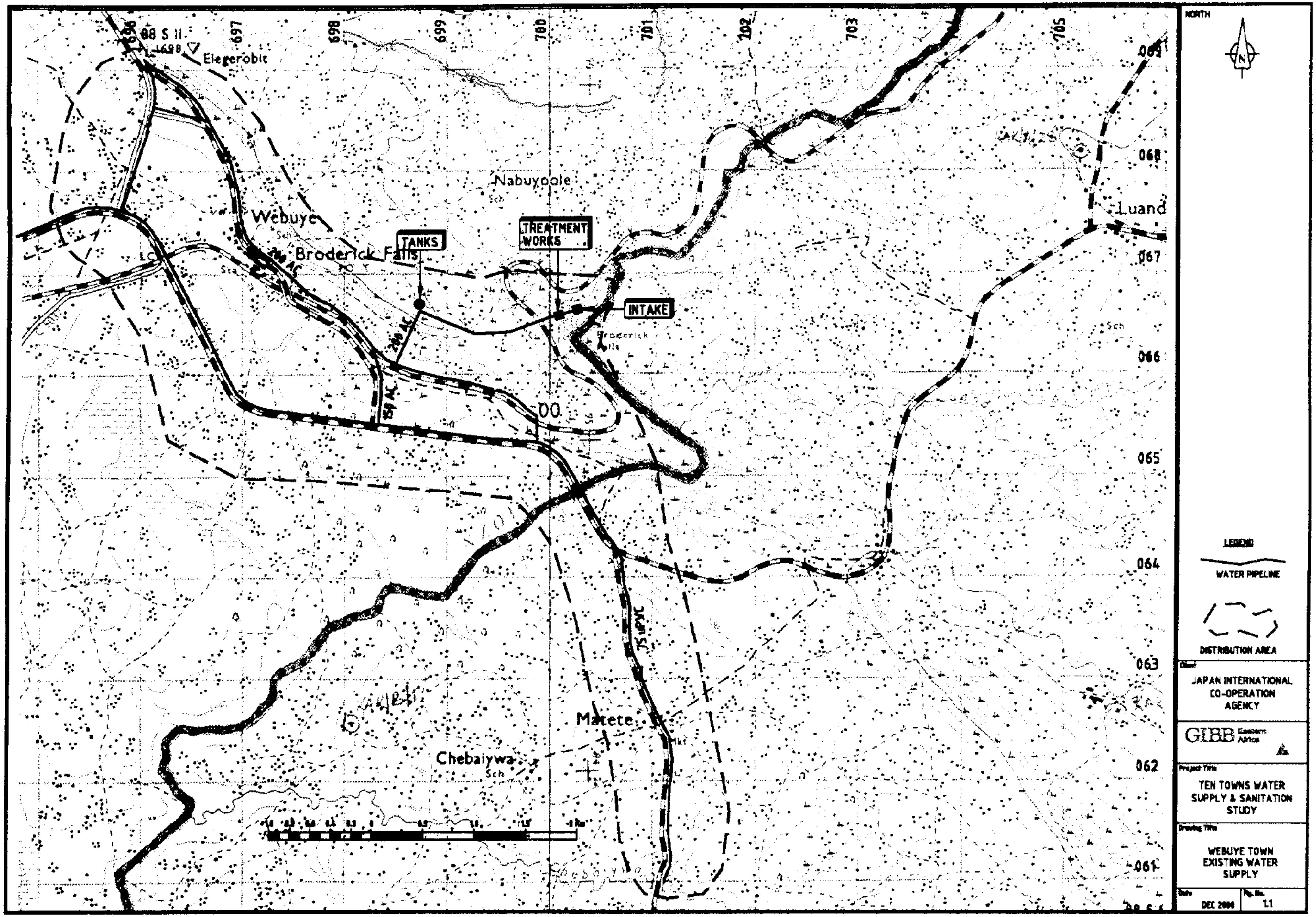
| | |
|---|---|
| AC | Asbestos Cement (Pipe) |
| AFW | Accounted for water |
| AG | Attorney General |
| AIDS | Acquired Immune Deficiency Syndrome |
| AIE | Authority to Incur Expenditure |
| AMREF | African Medical Research Foundation |
| ASK | Agricultural Society of Kenya |
| ATP | Ability to Pay |
| bgl | Below ground level |
| BH | Borehole |
| BOT | Board of Trustees |
| BPT | Break Pressure Tank |
| CBD | Central Business District |
| CBR | Cost Benefit Ratio |
| CIM | Centre for International Migration |
| CMT | Core Management Team |
| CTB | Central Tender Board |
| CV | Contingent Valuation |
| CWS | Community Water Supplies |
| DAF | Daily Average Flow |
| DCO | District Commissioner's Office |
| DDC | District Development Committee |

| | |
|---|---|
| DWD | Department of Water Development |
| Dia | Diameter |
| DTO | District Treasury Office |
| DWE | District Water Engineer |
| DWF | Dry Weather Flow |
| DWO | District Water Office(r) |
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| ENEP | El-Nino Emergency Project |
| FIRR | Financial Internal Rate of Return |
| FY | Financial Year |
| GAA | German Agro Action |
| GI | Galvanized Iron |
| GoK | Government of Kenya |
| Gph | Gallons per hour |
| GPS | Global Positioning System |
| GTZ | German Technical Assistance |
| H | Head |
| Ha | Hectares |
| HO | Head Office |
| HQ | Headquarters |
| IEE | Initial Environmental Examination |
| ITCZ | Inter-tropical Convergence Zone |

| | |
|---|---|
| JICA | Japan International Cooperation Agency |
| KEFINCO | Kenya-Finland Co-operation |
| KEWI | Kenya Water Institute |
| Km | Kilometer |
| $Km^2$ | Square Kilometers |
| KP&LC | Kenya Power and Lighting Company |
| KR | Kenya Railways |
| Kshs | Kenya Shillings |
| L | litre |
| LA's | Local Authorities |
| L/c/d | Litres per capita per day |
| LPO | Local Purchasing Order |
| L/sec | Litres per second |
| $M^3$/day | Cubic meters per day |
| $M^3$/hr | Cubic meters per hour |
| MENR | Ministry of Environment and Natural Resources |
| MoLG | Ministry of Local Government |
| MTB | Ministerial Tender Board |
| MW | Mega-watts |
| NAWARD | National Water Resources Database |
| NEAP | National Environment Action Plan |
| NEMA | National Environmental Management Authority |
| NGO | Non-Governmental Organisation |

| | |
|---|---|
| NPV | Net Present Value |
| NTU | Nephelometric Turbidity Units |
| NWC&PC | National Water Conservation and Pipeline Corporation |
| NWMP | National Water Master Plan |
| ODA | Official Development Assistance |
| O&M | Operation and Maintenance |
| PE | Polyethylene Pipe |
| PSP | Private Sector Participation |
| PVC | Polyvinyl Chloride |
| PWO | Provincial Water Office(r) |
| Q | Discharge |
| RDF | Rural Development Fund |
| RER | Revenue Expenditure Ratio |
| RGS | River Gauging Station |
| RHS | Random Households Survey |
| SIDA | Swedish International Development Agency |
| SS | Subordinate Staff |
| STD | Subscriber Trunk Dialing |
| STW | Sewage Treatment Works |
| TDS | Total Dissolved Solids |
| ToT | Training of Trainers |
| T-Works | Treatment Works |
| UFW | Unaccounted for water |

| | |
|---|---|
| UNICEF | United Nations Children's Fund |
| WHO | World Health Organization |
| WMS | Welfare Monitoring Survey |
| WRAP | Water Resources Assessment Project |
| WS | Water System |
| WSS | Water Supply System |
| WTP | Water Treatment Plant |



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# 1 INTRODUCTION

## 1.1 BACKGROUND OF THE STUDY

Kenya's water and sanitation sector is in critically poor condition. Like in many developing countries, the sector is plagued by a series of problems. These problems have arisen because of lack of technically sound operation and maintenance practices resulting in a backlog in rehabilitation, and above all, poor utility management. The existing institutional framework and organizational procedures result in bottlenecks and failure to create required authority and responsibility capacity at the most beneficial levels. Lack of autonomy for the managers of water utilities at all levels is one of the key causes for sustained inferior performance.

The tremendous pressure occasioned by population increase, rural-urban migration and unplanned settlements have strained the water and sewerage schemes beyond the original design capacities.

Periodic technical and financial reviews of water services in Kenya and the Aftercare Study on Kenya's National Water Master Plan have revealed that there is need for serious re-evaluation of management of water and sanitation utilities to meet the targets of effective service delivery in support of the integrated development plans. Decentralization of decision making and management to the local levels and transferring to the private sector activities that can be carried out without compromising social, health or vital economic requirements of the population are of cardinal importance.

Against this background, the Government of Kenya recently approved the National Water Policy paving the way for legislative changes in the Laws of Kenya that touch on water activities. The changes aim at rationalizing management, decentralizing operations to the local level, creating the necessary regulatory framework and activating private sector participation in the sector, in order to obtain a more responsive management system that ensures efficient service delivery and project sustainability at the most economical cost.

JICA, one of Kenya's leading development partners, would like to help create a sustainable environment for water and sanitation service delivery systems, by supporting formulation and development of workable management arrangements in the water sector.

The Study on Institutional Improvement and Rehabilitation of Water Supply Systems for Ten Local Towns is being undertaken in order to provide Kenya with feasible, viable and implementable options that are sensitive to local conditions, especially social, environmental, economic and political.

The findings, recommendations and work plans derived from this study may then be used to develop a more comprehensive framework for rehabilitation and extension of water services to meet development objectives as enshrined in the National Poverty Eradication Plan for the rest of the nation.

The use of local initiatives such as Kitale and Nakuru to investigate the potential and/or constraints for commercialization of water services within local authority setting will be a useful barometer for the future of the National Water Policy, which envisions decentralization of water activities to local authorities in urban areas. Malindi, which is under a partnership between the National Water Conservation and Pipeline Corporation and Gauff Utility Services, will provide another alternative for comparison of performance and benchmarking.

## 1.2 OBJECTIVES OF THE STUDY

The objectives of the study are:

(1) To obtain the baseline information regarding the water supply systems for the ten local towns;

(2) To recommend the institutional arrangement for effective water service delivery and rehabilitation plan of the relevant facilities in the project areas;

(3) To give advice on the application of the recommendation to the other areas in the Republic of Kenya.

## 1.3 SCOPE OF THE STUDY

The fundamental philosophy of this study hinges on the fact that without appropriate intervention in the water supply and sanitation sector, no major improvements in service delivery will be realized. This study focuses on ten (10) towns in the Republic of Kenya namely: Meru, Lamu, Kabarnet, Webuye, Mumias, Migori, Narok, Muranga, Makindu, and Wundanyi as a pilot programme of implementing the desirable interventions which will serve as a show case for replication in the rest of the country.

The interventions entail three main components, which must go hand in hand:

(1) To restore the water supply and sanitation facility to its original technical and functional capacity by undertaking the necessary physical rehabilitation.

(2) To put in place an appropriate institution to run the water supply and sanitation facility. This institution should be more responsive to the needs of, and directly answerable to the consumers. The institution should have the legal backing and formed in line with the current National Water Policy, which advocates active private sector participation in the water sector for more efficient service delivery.

(3) To put in place an appropriate technical team of operators, with the necessary skills and equipment and tools to take over the day to day operation and maintenance of the rehabilitated facility. It is envisaged that a team starting with an efficiently functioning facility free of major repairs and replacements, and with a good management backing,

stands a better chance of achieving a self-sustaining facility within a reasonable time span.

In order to achieve the foregoing intervention goals and the overall project objectives, the study entails a two-phase strategy for collecting the relevant data and information: a Preliminary and a Pre-feasibility phase.

The preliminary study covers review of relevant data and information, diagnostic survey of existing water supply and sanitation facilities, water demand projection, revision of water supply facility plan, cost estimation and evaluation, identification of the laws and regulations of environmental impact assessment, legal and regulatory framework on facility performance. It entails basic data collection, field reconnaissance and field inspection of the utilities to assess the current condition and situation of the water supply and sanitation schemes.

The pre-feasibility study phase covers establishing the socio-economic characteristics of the study area, assessment of surface water and groundwater potential, identification of institutional and legal constrains that affect improvement in operations of water facilities and determination of viable financial and commercial plans that ensure long-term sustainability of the facilities.

The pre-feasibility phase includes review of existing data, evaluation of the technical, socio-economic, institutional and financial aspects, formulation of water supply and sanitation facility rehabilitation plans, and formulation of preliminary technical and institutional development plans on which recommendations will be based.

In addition to the ten towns that constitute the pilot programme, operational experiences have been obtained from the towns which have been undergoing the commercialization approach, promoted by GTZ, i.e. Malindi, Kitale and Nakuru, for comparison purposes. The year 2010 has been chosen as a planning horizon.

## 1.4 COMPOSITION OF THE FINAL REPORT

The final report comprises of a total of two volumes as follows:

Volume 1: Executive Summary
Volume 2: Main Report

As indicated by their titles, Volume 1 is a summary of the study while Volume 2 is a presentation of the full town report including supporting and back-up data.

# 2 EXISTING PHYSICAL AND SOCIO-ECONOMIC CONDITIONS

## 2.1 GEOGRAPHY OF THE STUDY AREA

### 2.1.1 Location

Webuye Municipality is located in Webuye Division of Bungoma District in the Western Province.

The town boundary encloses an area of approximately 27 km$^2$.

### 2.1.1 Topography

Webuye town lies some 3 km to the west of the Webuye (Broderick) Falls on the Nzoia River. The town is bounded to the north by a range of hills and to the south by the Nzoia River, which forms the administrative boundary between Bungoma and Kakamega Districts.

Ground levels within the town range from approximately 1,450 m AMSL near the waste stabilisation ponds to approximately 1,590 m AMSL at the service reservoir site.

### 2.1.2 Geology

Webuye is located at the foot of the northern extremity of the Nandi Escarpment, a range of Basement System and granitic rocks that have been upthrust to elevations of over 2,000 m AMSL. Around Webuye the escarpment is more subdued, rising to 1,700 m AMSL at Elegerobit Hill, north-west of the town. The lower land that stretches from the scarp undulates between 1,400 m AMSL to 1,500 m AMSL.

The Nandi Escarpment is a tectonic feature delineating the northern limit of the Nyanza craton. This area was downwarped during the events that formed present-day Lake Victoria. The geology of Webuye area is therefore characterised by both Basement and Nyanzian system rocks. The Basement rocks here comprise gneisses, and crystalline limestones. Nyanzian System rocks consist of metavolcanics and banded ironstones. Granite intrusions emplaced during the Nyanzian Event are also found in the area. The detailed petrology of these rocks is of little relevance to water resources. The overburden in this area typically comprises laterite and reddish-brown clays.

### 2.1.3 Climate

The mean annual rainfall is 1,400 mm, with a mean annual evaporation of less than 2,000 mm. Rainfall is distributed bi-modally. The aridity ratio for Webuye (rainfall divided by evaporation) is approximately 0.7, which makes it a humid area.

## 2.2 PHYSICAL INFRASTRUCTURE

### 2.2.1 Communications

2.2.1.1 Road links

Webuye lies on the A104 tarred highway from Nairobi to Uganda. The railway line to Uganda also passes through the town.

2.2.1.2 Rail links

The railway line from Mombasa to Uganda passes through the town.

2.2.1.3 Telecommunications

Telephone services and fax facilities are available in the town.

### 2.2.2 Power supply

Webuye is connected to the national power grid.

### 2.2.3 Water supply and sanitation infrastructure

This is the subject of the present study and a detailed evaluation of the water supply and sanitation infrastructure is included in the chapters that follow.

### 2.2.4 Existing and planned services

There are existing water, sewerage, electricity and telephone services in Webuye. The El Nino Emergency Project to improve water supply facilities is in the implementation phase.

## 2.3 SOCIO-ECONOMIC CONDITIONS

### 2.3.1 Administration

Webuye is a cosmopolitan town situated in Bungoma district within western province of Kenya. It is divided into Maraka, Matulo and Township sub locations., The present township (CBD) as constituted in the 1970's, is considered to cover an area of approximately 13.8 $km^2$. About 60% of this area is classified as rural (see map I1-2). The significance of the town arises from establishment of the Pan Paper Pulp factory in 1975. As an administrative headquarters of Webuye division, its Central Business District (CBD) houses offices of the district officer, other divisional departmental heads and municipal offices as well as offices of a few non-governmental organizations operating within the town. The infrastructural potential of the town enables it to serve as a major economic hub for neighboring Kimilili, Ndivisi, Luandeti and Matete divisions.

### 2.3.2 Population Structure and distribution

Using the 1999 housing and population census, the population of Webuye town was 70,137[1] people as at 1999. This contrasts with the 1979 and 1989 censuses where the total population was 10,000 and 17,963 respectively representing an inter censal growth rate of 9.71% for 1989-1999 period. The number of households increased from 6,197 in 1989 to 15,355 units in 1999 with a mean household size of 5.6. There was an increase in urban settlement as the urban population density (considering the CBD) was 579 persons per $km^2$ in 1989 compared to 1,571 in 1999. The distribution of the population and number of households on the basis of sub locations and water service area is shown in **Table 2.1**. (See appendix I 1-1 for a map of the study area).

[1] This excludes non-residential population but includes the special population. Special population in this regard based on the 1999 census enumeration procedures considered to include though not restricted to people in hotels/lodgings, bus stops, police cells, on transit, idlers and street urchins found within the town as at mid-night of the census enumeration day.

**Table 2.1: Population Structure and Distribution**

| Sub-Location | Number of Households | Population in Municipality | Population in Service area |
|---|---|---|---|
| Maraka | 1,521 | 8,141 | 40,882 |
| Matulo | 1,706 | 8,402 | |
| Township | 5,690 | 21,675 | |
| Kivaywa | 2,010 | 8,345 | |
| Misikhu | 3,130 | 7,271 | |
| Malaha | 1,298 | 16,303 | |
| | **15,355** | **70,137** | **40,882** |

*Source: District Statistical Office, Bungoma and Central Bureau of statistics, 2001*

## 2.6 Population Projections to 2010

The 1989-1999 inter censal growth rate for the town based on the 1999 housing and population census aggregate results was 9.71% compared to 4.35 % in 1979-1989 period. The increment in growth rate is at variance with the national trend that declined due to reduced fertility rates and a fall back in job opportunities in urban areas. The high inter censal growth rate for 1979-1989 periods is attributed to the rapid industrial growth of the town due to establishment of the Pan African paper Mills and the East African heavy chemical industry in the late seventies. There were no major investments in the town during the 1989-1999 inter censal period and it is expected that the investment climate will for the next ten years remain relatively stable. Consequently, population growth a growth rate of 4.05% was developed and adopted for making the projections over a ten year period as shown in **Table 2.2**.

**Table 2.2: Population Projections to 2010**

| Year | Population under Municipal Council |
|---|---|
| 2000 | 73000 |
| 2001 | 76000 |
| 2002 | 79000 |
| 2003 | 82200 |
| 2004 | 85500 |
| 2005 | 89000 |
| 2006 | 92600 |
| 2007 | 96400 |
| 2008 | 100300 |
| 2009 | 104300 |
| 2010 | 108500 |

### 2.3.4 Economic and Commercial Activities

The Pan African Paper Mills has since its inception in 1974 dominated the economic, social and environmental landscape of the town as it runs its own water supply network. The nearby E. A. Heavy Chemicals factory, the Nzoia sugar factory, a number of small to medium potential enterprises, hotels and housing estates are the major growth sources for the central business district. The potential for growth of the ton is enormous especially private production of timber by the peri urban locals. Most commercial activities found within the municipality are geared towards meeting the needs and expectations of the farming community. Major among them are distribution, wholesale and retail shops. Bicycles commonly called *boda boda* also form a major player in the transport industry and is currently a rapidly growing industry employing many youths. The cumulative effect of these activities is growth in consumer expectations as wellas a derived demand for utilities. **Table 2.3** shows the distribution of business enterprises in Webuye town.

**Table 2.3: Business enterprises**

| **Activity** | **Number in 1999** |
|---|---|
| General Retailers | 164 |
| Wholesalers | 18 |
| Bars | 36 |
| Hardware Shops | 13 |
| Carpentry Workshops and Timber Traders | 22 |
| National Cereals and produce Board | 1 |
| Posho Mill | 25 |
| Slaughter house | 1 |
| Bakery | 1 |
| Bookshops | 5 |
| Manufacturing | 2 |
| Food Kiosks | 70 |
| Hotels | 23 |
| Tailoring | 41 |
| Kiosks | 61 |
| Butchery | 25 |
| Boutique | 3 |
| Saloon | 5 |
| Chemist | 5 |
| Petrol Stations | 3 |
| Jua Kali Activities and garages | 54 |
| **Total** | **578** |

*Source: District trade Office, Bungoma*

### 2.3.5 Social Infrastructure

2.3.5.1 Communication

Webuye town is connected to an A classification trunk road (the great north road) from Eldoret to Malaba. It is well connected to all the major towns within the region. The feeder roads are all weather murram roads and are regularly maintained by the Nzoia Sugar factory. It may be considered that road network is in a fairly good condition and all roads are motorable. A railway line passes through the town with a diversion to pan paper. Other services include subscriber trunk dialing (STD) telephone services, fax facilities, Internet service bureaus as well as an airstrip three kilometres away for light aircraft.

2.3.5.2 Social Institutions

The growth of Webuye town is dependent on the outreach activities of pan Paper Mills as well as the local Nzoia sugar factory. Institutional growth such schools and health facilities has been phenomenal. The main types of institutions and their distribution in terms of numbers are summarized in the **Tables 2.4 and 2.5.**

**Table 2.4 Educational Institutions**

| **Type of institution** | **Number** |
|---|---|
| Pre-Primary Schools | 39 |
| Primary Schools | 15 |
| Secondary Schools | 3 |
| Youth Polytechnics | 5 |
| **Total** | **62** |

*Source: District Development Office Bungoma, 1999*

**Table 2.5 Other Social Institutions**

| **Facility** | **Number** |
|---|---|
| Nursing homes | 2 |
| Health Centres | 3 |
| Sub-District Hospital (GoK) | 1 |
| manufacturing | 3 |
| Private Clinics | 12 |
| Mosques | 3 |
| Social hall | 1 |
| Stadium | 1 |
| **Total** | **26** |

*Source: District Development Office Bungoma 1999*

### 2.3.6 Income Levels

The distribution of income in the town is quite uneven as it reveals major disparities in household resource endowment. Employees of Pan Paper, Nzoia Sugar company, government departments and NGO's dominate the town's cash transactions. As a result, the town experiences a high turn over in monetarised transactions. This is however mainly concentrated within the town as urban dwellers earn through wages, salaries and profits which accounts for about 44% of the urban households mean monthly income.

According to results of the Welfare Monitoring Survey (WMS) II, the mean monthly household income for the town and its environs was estimated to be Kshs. 7,981.7 as shown in table 2.6. Households living in the low income areas derive their meager incomes from farming and other related activities. This means that basing the analysis on existing tariff structure, most of the urban population of Webuye town are able to pay for water. A random survey conducted by the study team mainly focusing on the low income groups based on a random sample of 80 households revealed that more than half of the households interviewed earn an average income of over Kshs 5,000 per month from different sources. During the teams tour of the town, it came out quite clearly that the problem at the moment may not be the level of the tariff but rather the level of service considering that most of the households pay as high as Kshs 10 to 25 for a 20L jerricane of untreated water delivered by vendors and other sources such as *boda boda*.

**Table 2.6 Mean Monthly Household Incomes (Kshs).**

| Income Source | Mean |
|---|---|
| Wages/Salaries/profits | 3112.1 |
| Other Non-agriculture income | 1228.0 |
| Agriculture income | 2257.1 |
| Crop income | 1374.4 |
| **Total household income** | **7981.7** |

*Source: Welfare Monitoring Survey II, 1994*

### 2.3.7 Willingness and Ability to Pay for Water Services

2.3.7.1 Ability to Pay

Ability to pay is a function of level of household incomes, the acceptable share of water/sewerage services in total expenditures, tariffs, the target consumption levels and peoples awareness of safe water sources. However, the main consideration in the ability to pay in this study is the household level of income. The ceiling on the proportion of income that may be spent for water/sewerage services is usually taken to be 5% though this varies from one income group to another. The most basic observable feature here was that households in the lower income bracket spent a higher budget share of their income in real terms on water than households in the middle to high-income group who spent 2.2% and 1.4 % of their incomes respectively.

51% of the population in this local town live in the low-income bracket under very poor sanitary conditions and are considered to draw water from untreated sources in times of acute shortage. Therefore, a re-evaluation of their income levels W/ATA and W/ATP is integral and forms an important component of the perceived water and sanitation improvement plan.

#### 2.3.7.2 Willingness to pay

To get information on willingness to pay[2] the study team carried out a random survey on a sample of 80 households mainly within the service area. Through questionnaire based interviews, each household head was asked questions on how much they would be willing to pay for a cubic meter of water assuming improved service delivery.

The general conclusion of the survey was that most households were willing to pay more for improved water supply commensurate with the level of tariff increase and subject to an individual's perception of the water problem in a particular area. This means that it is important to note that satisfaction of the expectations of consumers form an important component of their decision making process.

For instance, 80% of the households interviewed were willing to pay up to Kshs. 500 for actual water consumption compared to an average monthly bill of Kshs. 300, which in most cases is developed through questimates. And based on existing tariff structure, water availability, billing inadequacies and general decline in commitment of interest on the part of the water undertaker, a rehabilitation exercise that takes into consideration this inadequacies is likely to affect peoples W/ATP and W/ATA positively.

A similar survey in the areas not currently serviced established that majority of the households would be willing to pay for water at the current general water tariff of Kshs. 30/m$^3$ especially considering that the

[2] The appropriate methodology in estimating willingness and ability to pay (W/ATP)/ willingness and ability to accept (W/ATA) is to use the contingent valuation (CV) approach. This approach is validated through asking water consumers at the household level hypothetical questions (which are a true reflection of actual water consumption levels) how much they are paying for water as compared to how much they would be WTP if existing water supply externalities are internalized.

hinterland population travel long distances if they have to get piped water. Simulations to establish the threshold tariff beyond which people would not be willing to pay revealed that even with increment of up to 30% in the tariff, people would still be willing to pay

### 2.3.8 HEALTH AND SANITATION SITUATION

The team critically analyzed the health and sanitation conditions of the town. Though about 76% of the populations have access to pit latrines, some people prefer to use what is locally called 'flying toilets'.

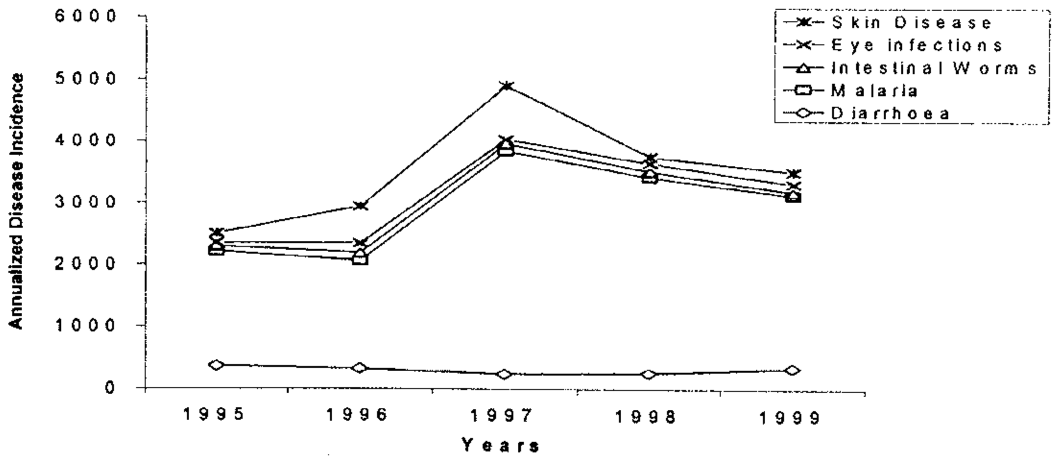
'Flying toilets' is a common case of surface pollution to the main sources of water supply to the hinterland i.e. from storm water to springs.

According to a report availed to the study team on bacteriological examination of water within the municipality, it was noted that high levels of sanitation lapses are experienced and surface water contamination through ground water infiltration is common. For instance, a 1994 report from the government chemist Kisumu showed that there was a high-level water contamination with faecal organisms, which is obviously a serious health threat to the unsuspecting population living especially in the low-income areas. To forestall a pandemic outbreak of any water borne disease, health education and sensitization seminars need to mounted regularly based on information obtained from monthly monitoring and outreach clinics

Based on information obtained from the Health Information systems unit at Afya house in Nairobi, it may appear like the incidence of diarrhoeal diseases is mild and hence of no serious consideration in a water rehabilitation programme. It is however important to note that like many health facilities in Kenya, methods of data capture and storage in health facilities in Webuye is poor especially when analyzed on a retrogressive basis. Given the prevailing health conditions based on a casual examination of the town, it is instructive that more cases passs unreported.

Disease prevalence pattern in the town based on information collected from the PHO shows that the top five common diseases of economic importance are malaria, acute respiratory infections, diarrhoea diseases, urinary tract infections and skin diseases. Occurrence of water borne diseases within the town is as shown in the chart 1. It may be important to note that the incidence of diarrhoeal diseases are low mainly due to a negative health seeking behaviour among urban residents.

Chart 1: Incidence of water related Diseases in Webuye Town




*Source: Information Health Systems unit, MOH and PHO Webuye, 2001*

### 2.3.9 TYPES OF SETTLEMENTS

Employees of Pan paper and other government departments stay in the affluent estates dominated by permanent structures. However, within the peri–urban areas, the most common structures are semi permanent and mud walled buildings. Table 2.7 shows a simple classification of the urban population on the basis of broad income categories.

**Table 2.7 Categorization of households on the basis of income levels**

| Income category | Number | Percentage |
|---|---|---|
| High income | 9117 | 13 |
| Middle income | 26652 | 38 |
| Low income | 34368 | 51 |
| **Total** | **70,137** | **100** |

### 2.3.10 Situation of Women in Society

Traditionally, women in Kenya are responsible for collecting water for domestic use in the household. They are conceivably one of the most abused group with regard to water collection habits making them a major vulnerable group in society. Just like poverty, collecting water is a circumstance women find themselves in and which does not necessarily define them.

Collecting water for the household can therefore have negative repercussions on the length and hardship of an average poor woman's working day. Despite the government pre commitment that by the year

2010, all households should have access to water within a radius of 2 kilometres, this situation is yet to be realized especially within the peri-urban areas. This therefore means that the rehabilitation exercise planned for the towns must meet societal expectations in order to ease the excess burden on the woman and an average woman's workload should be a key monitoring indicator.

Other than situations where hand cats, *boda boda's* and pick up vans are used, the burden for carrying water requires women to have a substantial amount of energy. This condition is energy sapping and causes considerable stress especially to pregnant women leading to multiple complications at childbirth. Other causes of stress include headaches, backaches, sometimes and deformation of the spine. Accidents do occur and these include slipped discs, paralysis, injury to children carried on the back to extreme cases such as strangulation by the head strap. Improved water supply conditions would change all these and ease the burden on women, releasing time and energy for other development activities necessary in nation building.

## 2.4 EXISTING WATER RESOURCES, MANAGEMENT AND UTILISATION

### 2.4.1 Hydrogeology and occurrence of groundwater

The hydrogeological conditions in the Webuye area can be summarised as follows:

- Depth range to the main aquifer: 30 – 70 m.
- Depth range of water rest level: 6 – 10 m.
- Discharge range: 3 – 10 $m^3$/hr.
- Water quality: Although little information is available, the groundwater here is expected to be fresh, but slightly alkaline. The ionic concentrations of iron, manganese and silica may be high.

Aquifers are mainly confined, occurring in weathered and fractured zones. The aquifers comprise overburden and *in-situ* weathered material. Fractures may produce deeper confined aquifers. Recharge to the aquifers occurs by lateral underflow from recharge catchments in the Cherangani hills and lower slopes of the Mt Elgon hill range. Local infiltration also contributes to recharge.

The Water Department in Webuye Town does not operate any boreholes. However, a few private boreholes have been drilled in outlying areas. These boreholes were not inspected because they do not constitute sources operated and maintained by the local Water Department.

Table 2.8 presents data for the existing boreholes.

**Table 2.8**
**Completion data for institutional boreholes**

| Serial No. | Total depth m | Water strike levels m | Rest level m | Tested yield $m^3/hr$ | Owner |
|---|---|---|---|---|---|
| C-10188 | 65 | 18, 33 | 9.0 | 5.0 | KEFINCO |
| C-10609 | 64 | 22, 44 | 7.3 | 3.0 | St Joseph's School |

*Data source: NAWARD, MENR*

### 2.4.2 Groundwater potential

2.4.2.1 Hydrogeological units

The hydrogeological units in the Webuye area are complex due to its location at a major tectonic junction and geological boundary. Aquifers occur in the overburden, weathered and fractured zones.

Basement System hydrogeological units

Where water is struck in gneiss, the aquifer is usually in the weathered saprolite or in fractured rock below the saprolite. Due to past tectonic activity in the area, it is possible that good fracture or fault-zone aquifers may be located.

Nyanzian System Hydrogeological Units

Aquifers in these rocks comprise overburden sandy or lateritic sediments, weathered or fractured rock. Aquifers in this unit generally have a higher potential than those in the Basement gneisses.

2.4.2.2 Recharge

Recharge to aquifers in the Webuye area is assured due to its location at the foot of the Nandi Escarpment. The area above the escarpment receives more rainfall than Webuye and forms an extensive catchment. The Nzoia River drops from the escarpment into the lowland at Webuye. This gap in the escarpment forms an important 'pipeline' for underground flow.

Recharge may also occur by lateral movement from the lower slopes of Mt Elgon along the tectonic boundary at the foot of the scarp.

#### 2.4.2.3 Outlook for groundwater development

The complex hydrogeological set up for Webuye makes generalisation unwise. Rather, it calls for more information, which at this stage of the current exercise is not available. However, the following conclusions are reached:

- Basement hydrogeological unit often gives rise to low to moderately high yielding aquifers, but not sufficient to maintain large abstractions as those expected for municipal water supplies.

- The Nyanzian System aquifers yield considerably more, but only detailed geological information can give an indication of their extent in the vicinity of Webuye Town.

### 2.4.3 Hydrology and surface water resources

The principal river in the vicinity of Webuye is the Nzoia River which rises in the Cherangani Hills. The main tributaries of the Nzoia include the Losarua, Moiben, Ndangesi, and the Noigamet. The lower catchment comprises the Kimilili, Kuiwa, Bokoli, Sosian, Kwoittobus and Chwele rivers which originate from Mount Elgon. The catchment falls in Sub-Drainage Area 1BD of the Lake Victoria Basin.

The rivers in the vicinity of Webuye are shown in Figure 2.1.

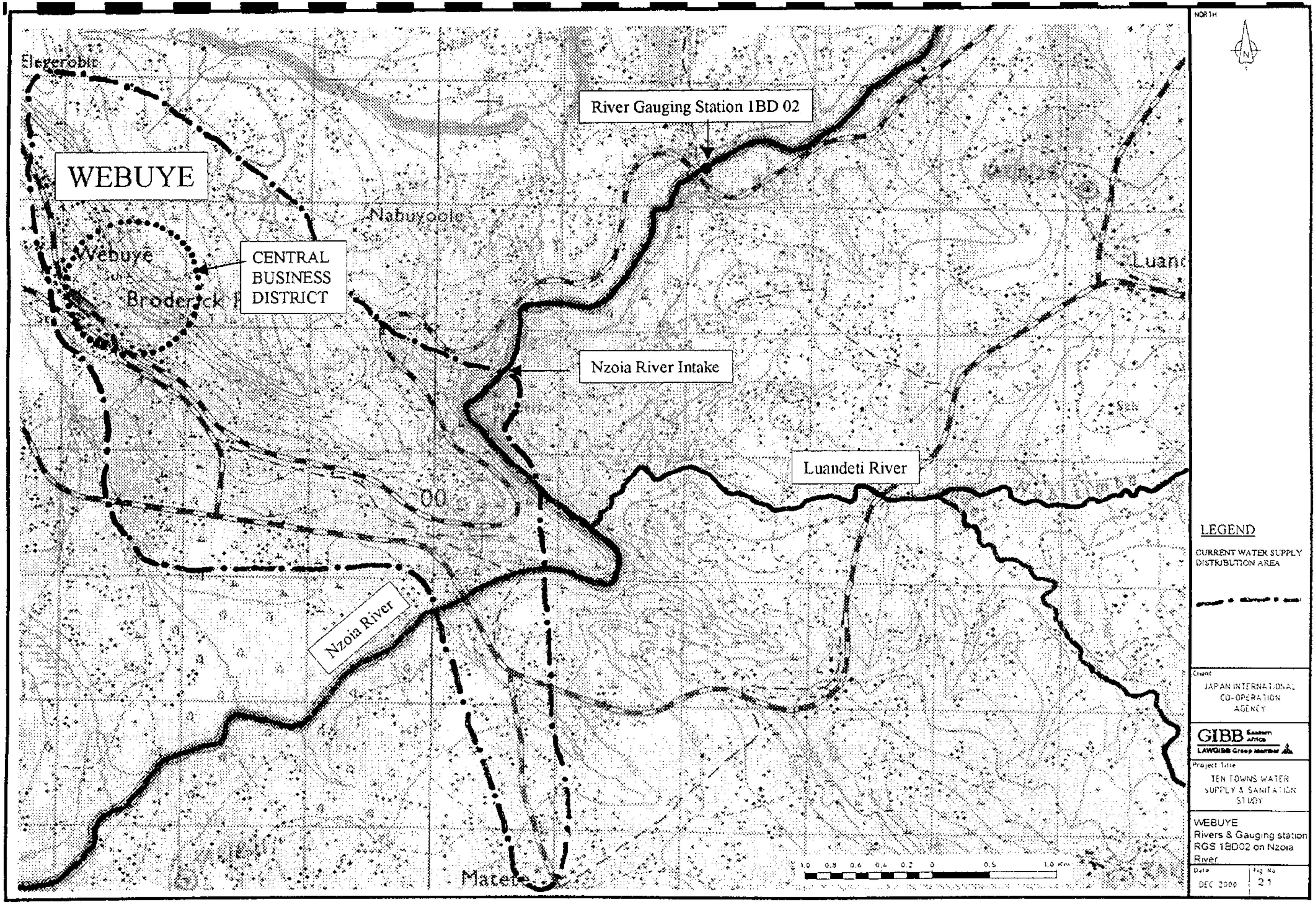
The source of public water supply in Webuye is the Nzoia River. Details of the nearest gauging station on the Nzoia River are summarised in Table 2.9.

**Table 2.9**
**Details of the nearest gauging station**

| Code | River | Latitude *** | Longitude *** | Station open | Station Closed | Rated | Catchment area ($km^2$) | Mean Annual Runoff ($m^3/s$) |
|---|---|---|---|---|---|---|---|---|
| 1BD02 | Nzoia | $00^0$ 45'40" | $34^0$50'40" | 1966 | 1972 | Yes | 3,950 | 14.9 |

*Source; The Aftercare Study on the National Water Master Plan Data Book, 1998*
****: The co-ordinates are incorrect and need to be corrected.*

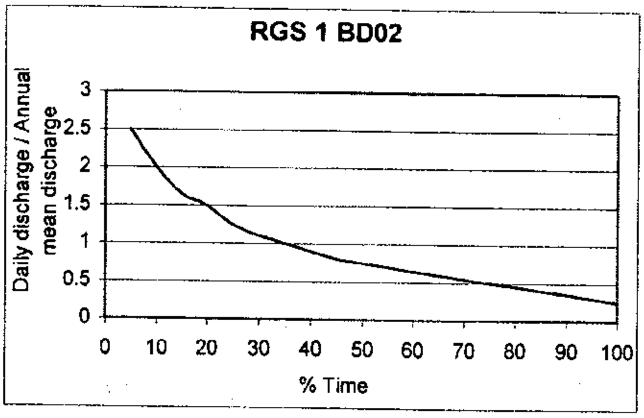
The non-dimensional flow duration curve for the Nzoia River is presented in Figure 2.2. This curve has been abstracted from the *"Aftercare Study on the National Master Plan"* published by JICA in


NORTH
N
River Gauging Station 1BD 02
WEBUYE
Elegerobic
Nabuyoole
Webuye
Broderick
CENTRAL
BUSINESS
DISTRICT
Luand
Nzoia River Intake
Luandeti River
Nzoia River
Matete
LEGEND
CURRENT WATER SUPPLY
DISTRIBUTION AREA
Client
JAPAN INTERNATIONAL
CO-OPERATION
AGENCY
GIBB Eastern Africa
LAWGIBB Group Member
Project Title
TEN TOWNS WATER
SUPPLY & SANITATION
STUDY
WEBUYE
Rivers & Gauging station
RGS 1BD02 on Nzoia
River
Date
DEC 2000
Fig No
21

1998. As very little additional data has been collected since the time of the JICA study, the curve is applicable today.

The flow duration curve shows the relationship between any given discharge and the percentage of time that the discharge is exceeded. The flow duration curve is derived from daily flow data by assigning daily discharges to class interval and counting the number of days within each interval. The proportion of the number of days above the lower limit of any given class interval is then calculated and plotted against the lower limit of the interval.

**Figure 2.2**
**Flow Duration Curve for the Nzoia River**




The 50% exceedence flow in Figure 2.2 is the daily discharge that was exceeded 50% of the time. The 100% exceedence flow is the flow that was exceeded 100% of the time during the flow sequence. Thus, the 100% exceedence value represents the lowest daily discharge on record.

The JICA "*Aftercare Study*" defined the yield of an unregulated river source as follows:

- "The reliable flow at a given site of a given river is defined to be a 90% dependable flow deducted by river maintenance flow ...", and
- "The 90% dependable flow is obtainable from the flow duration curve of the nearest gauging station ...".
- The maintenance flow is defined as "... the recorded daily minimum runoff of the river concerned".

Thus, the difference between the 90% and 100% exceedence flows corresponds to the available water resource. For consistency of approach, the same definition of reliable flow is adopted for this project.

The runoff characteristics are presented in Table 2.10.

The comparison of surface water yield and demand is presented in Table 2.11 for the Nzoia River RGS 1BD02. The surface water abstraction required for Webuye is a small proportion of the potential discharge in the Nzoia River.

**Table 2.10**
**Flow characteristics at RGS 1BD02**

| | |
|---|---|
| Mean annual runoff $Q_{ave}$ $m^3/s$ | 14.9 |
| 50% exceedence flow ratio $Q_{50}/Q_{ave}$ | 0.75 |
| 90% exceedence flow ratio $Q_{90}/Q_{ave}$ | 0.40 |
| 95% exceedence flow ratio $Q_{95}/Q_{ave}$ | 0.30 |
| 100% exceedence flow ratio $Q_{100}/Q_{ave}$ | 0.25 |

**Table 2.11**
**Comparison of Nzoia River yield at RGS 1BD02 and water demand**

| | **$m^3/d$** |
|---|---|
| Present abstraction capacity | 1,700 |
| 2000 water demand | 9,541 |
| 2010 water demand | 14,181 |
| 90 % exceedence flow | 515,000 |
| 100 % exceedence flow | 322,000 |
| Water resource available | 193,000 |

### 2.4.4 Raw water quality

Two partial water quality analyses for the Nzoia River were available in the Divisional Water Office, one dated 27 January 2000 and the other 9 March 2000. These are reproduced in **Table 2.12**.

**Table 2.12**
**Raw water quality**

| Sample date | 27 January 2000 | 9 March 2000 |
|---|---|---|
| PH | 7.68 | 6.5 |
| Colour | 220 | 121 |
| Turbidity (JTU) | 50 | 29 |
| Iron (mg/l as Fe) | .06 | Not determined |
| Manganese (mg/l as Mn) | <0.1 | Not determined |
| Alkalinity (mg/l as $CaCO_3$) | 70 | 72 |
| Chloride (mg/l as Cl) | 3 | 19 |
| Nitrite (mg/l as $NO_2$) | 0.003 | Not determined |
| Nitrate (mg/l as $NO_3$) | < 0.01 | Not determined |
| Ammonia (mg/l as $NH_3$) | 0.30 | 0.61 |
| Sulphate (mg/l as $SO_4$) | 31 | 2 |

The analyses are not sufficiently detailed to check the ionic balance and chemical classification of the water. The available records at the water treatment works show that the raw water has a pH of between 7.6 and 8.3.

The JICA funded *"National Water Master Plan"* reports that the sediment load of the Nzoia River is 112 mg/l.

### 2.4.5 Treated water quality

Table 2.13 presents two partial water analysis results, which were available at the time of field visit, for treated water: one dated 27 January 2000 and another dated 20 September 2000.

**Table 2.13**
**Treated water quality**

| Sample date | 27 January 2000 | 20 September 2000 |
|---|---|---|
| PH | 6.92 | 5.79 |
| Colour | 106 | Not determined |
| Turbidity (JTU) | 28 | Not determined |
| Iron (mg/l as Fe) | 0.02 | Not determined |
| Manganese (mg/l as Mn) | 0.1 | Not determined |
| Alkalinity (mg/l as $CaCO_3$) | 177 | Not determined |
| Chloride (mg/l as Cl) | 1.0 | Not determined |
| Nitrite (mg/l as $NO_2$) | <0.001 | Not determined |
| Nitrate (mg/l as $NO_3$) | <0.01 | 5.28 |
| Ammonia (mg/l as $NH_3$) | 0.2 | 2.02 |
| Sulphate (mg/l as $SO_4$) | 3 | Not determined |

The treated water is of poor quality, with high colour and turbidity. The sample dated 20 September 2000 has a very low pH and the values for nitrate and ammonia indicate contamination.

There are doubts about the analyses for 27 January 2000. The reported alkalinity increases from 70 mg/l to 177 mg/l during treatment, although no lime or soda ash is dosed. The reported sulphate reduces from 31 mg/l to 3 mg/l during treatment, despite dosing aluminium sulphate as a coagulant.

# 3 EXISTING WATER SUPPLY CONDITIONS

## 3.1 SOURCE AND INTAKE

### 3.1.1 Intake from Nzoia River

The intake chamber is situated on the second pool of the Webuye (Broderick) Falls. The concrete intake chamber is provided with a coarse screen. The level of the intake, taken from the available 1:50,000 mapping, is approximately 1,590 m AMSL.

### 3.1.2 Raw water main

There is a concrete gravity main from the intake to the water treatment works site. The length of the pipeline is approximately 300 m.

## 3.2 TREATMENT

### 3.2.1 General

At the time of our visit, there were two treatment streams in use:

- A conventional plant comprising upward flow clarifiers and rapid gravity filters, constructed in 1972;
- A proprietary "Struja" package treatment unit contained in two closed steel tanks.

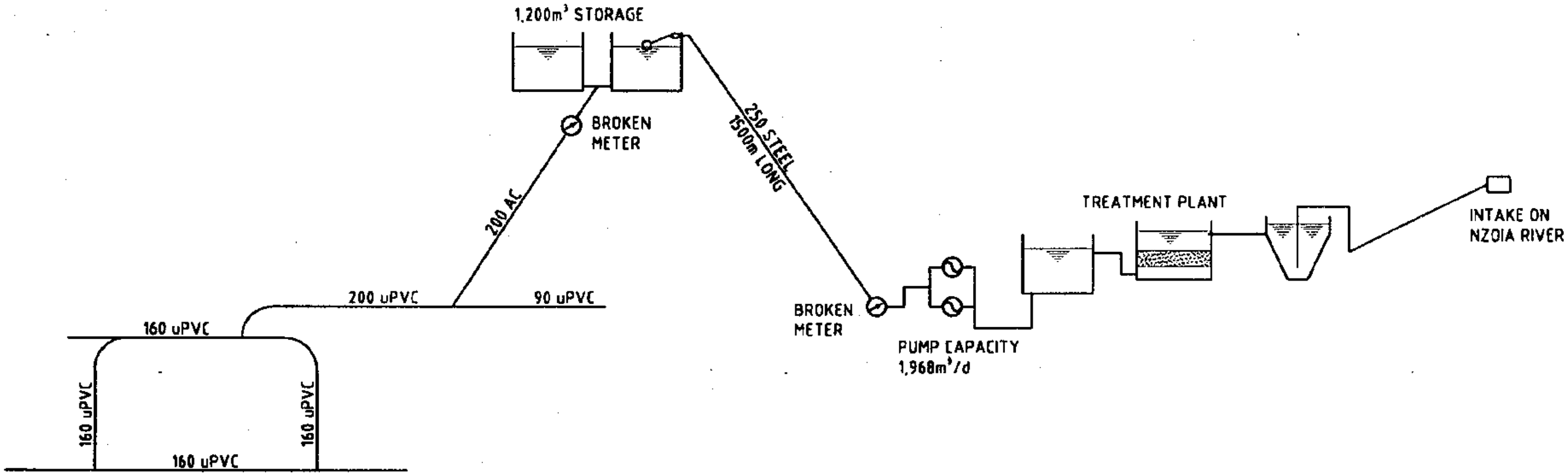
The conventional plant is being duplicated under the El Niño project.

### 3.2.2 Raw water quality

At the time of our visit, the operators at the water treatment works were recording the turbidity of the raw water as 190 NTU and the pH at between 7.6 and 8.3. There were no records of alkalinity at the water treatment works.

### 3.2.3 Coagulant preparation

Aluminium sulphate solution is prepared in a rectangular open tank at the head of the works. There is no mechanical mixer: the aluminium sulphate is stirred using a stick.



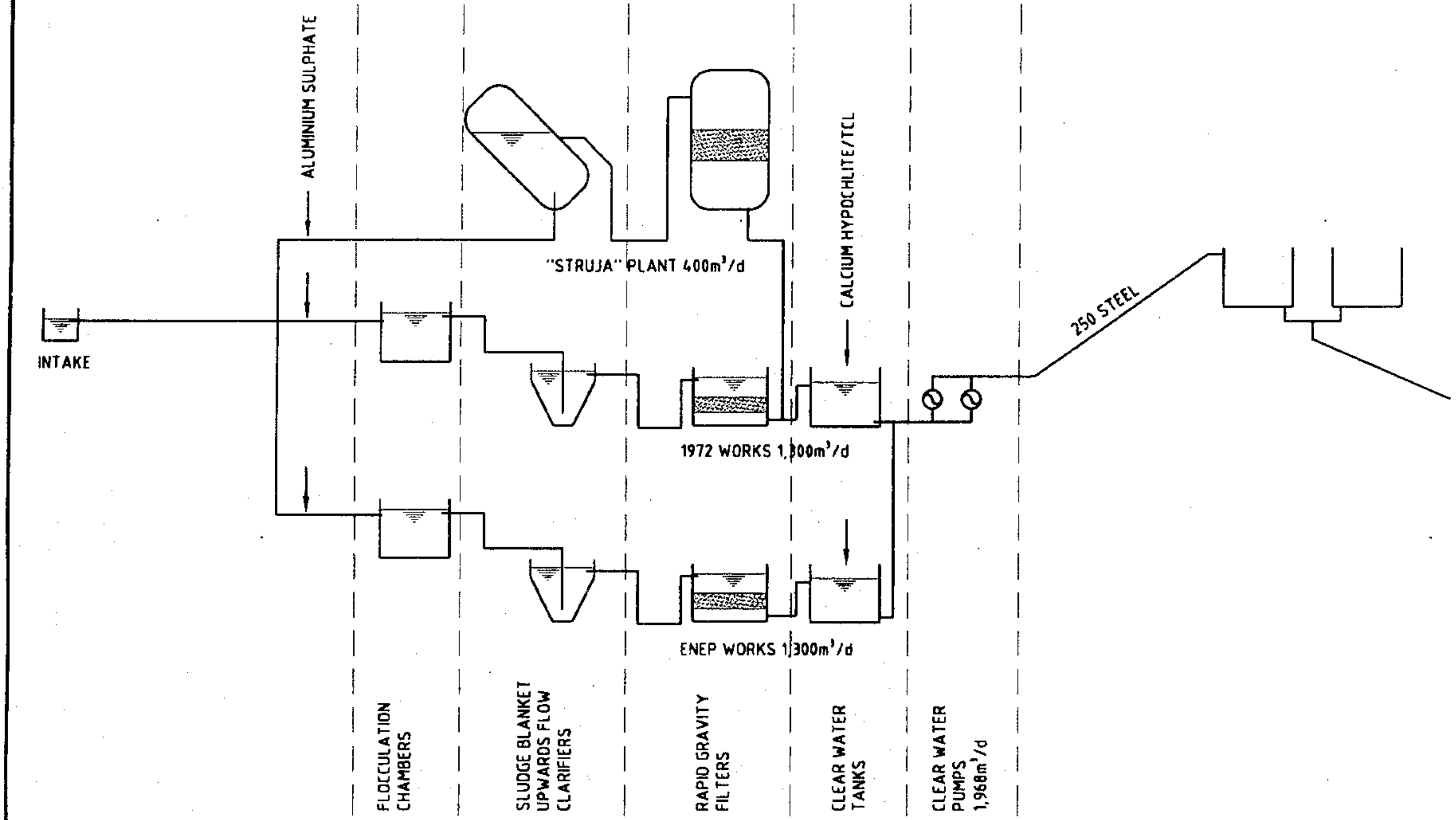

Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa
LAWGIBB Group Member

Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title
WEBUYE TOWN TREATMENT & DISTRIBUTION SCHEMATIC LAYOUT

| Date | Fig. No. |
|---|---|
| DEC 2000 | 3.1 |




Client: JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa — LAWGIBB Group Member

Project Title: TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title: WEBUYE TOWN WATER TREATMENT PROCESS

Date: DEC 2000 | Fig. No. 3.2

### 3.2.4 Flow division

There is no proper splitter box to proportion flow between the conventional and "Struja" plants: the incoming flow divides at a benched manhole.

### 3.2.5 The "Struja" plant

The "Struja" plant uses clarification and filtration in two sealed steel cylinders. Operations staff report that the unit has a capacity of 400 $m^3/d$.

### 3.2.6 The conventional treatment plant

3.2.6.1 <u>Clarifiers</u>

There are two hopper-bottomed, upward-flow clarifiers, each 4.57 m square, giving a surface area of 20.885 $m^2$. The 1986 design manual does not give design surface loadings for upward flow, sludge blanket clarifiers. In modern design practice, the design surface loading for upward flow clarifiers is between 1.5 m/hr and 2.5 m/hr, although the 1978 design manual stipulated a loading of between 1.2 m/hr and 1.5 m/hr. Adopting a loading of 1.5 m/hr, the units have a combined capacity of 1,504 $m^3/d$.

The District Water Office states that the capacity of the conventional plant is 1,400 $m^3/d$. This would correspond to a clarifier loading of 1.4 m/hr.

3.2.6.2 <u>Filters</u>

The conventional treatment plant has two rapid gravity filters, each 2.74 m by 2.21 m, giving a surface area of 6.062 $m^2$. The usual surface loading for rapid gravity filters is between 5.0 m/hr and 7.5 m/hr; the 1986 MENR Design Manual stipulates the lower value. Adopting a loading of 5.0 m/hr, the units have a capacity of 1,455 $m^3/d$.

The District Water Office states that the capacity of the conventional plant is 1,400 $m^3/d$. This would correspond to a filtration rate of 4.81 m/hr rather than the figure of 5 m/hr given in the 1986 Design Manual. This is a very conservative loading rate.

The filters are washed using water supplied from a header tank above the treatment works. There is no air scour. The wash rate using water only is typically 50 m/hr. For a filter area of 6.062 $m^2$ and a ten minute filter wash, the wash-water used is 20.3 $m^3$ per filter.

### 3.2.7 Treatment plant capacity

The capacity of the 1972 water treatment plant, determined from the filtration capacity at a loading of 5.0 m/hr, is 1,455 $m^3$/d. The combined capacity of the 1972 plant and the "Struja" unit is 1,855 $m^3$/d. Once the El Niño plant is commissioned, the combined plant capacity will increase to 3,310 $m^3$/d.

The District Water Office states that the capacities of the existing and El Niño plants are 1,400 $m^3$/d, giving a combined plant capacity of 3,200 $m^3$/d. As noted above, this nominal capacity gives a lower filtration rate than that stipulated in the 1986 Design Manual.

### 3.2.8 Coagulant dosing

Aluminium sulphate solution is dosed to both treatment streams. Dosing is under gravity from glass reinforced plastic solution tanks using gravity dosers. There are no mixers at the dosing points to distribute the solution through the incoming flow. The reported dosing rate is 64 mg/l, and the recorded usage is 100 kg/d.

### 3.2.9 Disinfection and the clear water tank

Tropical chloride of lime is dosed as a disinfectant at a reported rate of 1 mg/l into a clear water tank with a reported capacity of 650 $m^3$. A second clear water tank of 225 $m^3$ capacity is being constructed under the El Niño project. From the available 1:50,000 mapping, the level of the clear water tank is approximately 1,480 m AMSL.

### 3.2.10 Laboratory facilities

There is a laboratory adjacent to the clear water pumping station. There is no laboratory equipment, and dosage rates are set based on past experience.

### 3.2.11 Transmission main

The high lift pumps deliver to the service reservoir site through a 250 mm nominal bore steel pipeline some 1,500 m long. A tee from the main supplies the backwash tank on the hillside above the water treatment works.

### 3.2.12 High lift pumping

There are two Caprari MEC MR65-2/3A high-lift pumps, each with a nominal duty of 82 $m^3$/hr against 185 m head. One pump dates from 1984 and the other from 1999. The older pump is driven by a 75 kW, two-pole motor and the newer pump is driven by a 93 kW motor. Only one pump is presently operable, but they are to be repaired under the El Niño project. The nominal pump duty of 82 $m^3$/hr corresponds to a station capacity of 1,968 $m^3$/d.

From May to October 2000, the pumps were operated for 1,993 hours consuming 154,509 kWh of electricity. At a nominal flow rate of 82 $m^3$/hr, this represents a mean power consumption of 0.945 kWh/$m^3$ water pumped.

## 3.3 STORAGE

There are two circular service reservoirs, each with a reported capacity of 600 $m^3$, located on the hilltop above the town. These reservoirs were cleaned and painted under the El Niño project, and the storage site was fenced. The level at the service reservoir site is approximately 1,580 m AMSL.

Some consumers within Webuye have their own elevated storage tanks.

## 3.4 DISTRIBUTION

### 3.4.1 Distribution pipework

The main outlet from the service reservoir site is an 8" asbestos cement pipe that runs to the foot of the hill near Chocolate Estate. From here, a 3" uPVC pipe runs to the east and an eight inch asbestos cement pipe runs through the town to the west. One valve chamber can be seen on the 8" main, which contains an air release valve and what appears to be a pressure-reducing valve. Operational staff could not explain its purpose.

### 3.4.2 Consumer connections

Operational staff report that there are 2,106 connections to the reticulation system, of which 1,280 are active. Some consumers that were disconnected have illegally reconnected supplies using pieces of hose pipe to bridge the gap where the meter was removed.

## 3.5 EXISTING O&M

### 3.5.1 Administrative structure

The scheme is operated and maintained by the Divisional Water Office. The total staff complement for the Divisional Water Office is 28 of whom 27 are solely involved in the operation and maintenance of the Webuye gazetted water supply scheme. The remaining officer is responsible for monitoring water quality throughout Bungoma District. An organisational chart for the Webuye Divisional Water Office is given in Appendix 3.

### 3.5.2 Procurement of chemicals

Operations staff report that the Bungoma District Water Office delivers aluminium sulphate and calcium hypochlorite to the water treatment plant every week to ten days. The Water Quality Officer reports that chemicals are also "borrowed" from Pan Paper.

A company in Webuye, East Africa Heavy Chemicals Ltd., manufacture aluminium sulphate and sell at a factory gate price of Ksh 21.50/kg. Pan Paper, Nzoia Sugar Company and Mumias Sugar Company all buy their aluminium sulphate from this company, but the Webuye Divisional Water Office is not a customer.

### 3.5.3 Treatment process

The water quality analysis for the Nzoia River on 27 January 2000 shows a pH of 7.68 and an alkalinity of 70 mg/l. The analysis for 9 March 2000 shows an alkalinity of 72 mg/l, but a much lower pH of only 6.5. At the time of our visit in November 2000, aluminium sulphate was being dosed at 64 mg/l. This will consume 33 mg/l of alkalinity, lowering the pH of the water. The MENR water quality standards require the pH of treated water to be between 6.5 and 9.2, but preferably between 6.5 and 8.5. These standards clearly cannot be met without dosing soda ash to raise the alkalinity when the pH of the incoming raw water may be as low as 6.5.

The calculated coagulation pH and dissolved carbon dioxide when dosing aluminium sulphate at a rate of 64 mg/l are shown below.

**Table 3.1**
**Calculated coagulation pH and dissolved $CO_2$**

| Temperature (°C) | 10 | | 15 | | 20 | | 25 | |
|---|---|---|---|---|---|---|---|---|
| Raw water pH and alkalinity | pH | $CO_2$ (mg/l) | PH | $CO_2$ (mg/l) | PH | $CO_2$ (mg/l) | pH | $CO_2$ (mg/l) |
| 6.5, 72 mg/l | 6.07 | 86.7 | 6.05 | 81.0 | 6.04 | 76.7 | 6.03 | 73.4 |
| 7.68, 70 mg/l | 6.48 | 32.0 | 6.44 | 31.7 | 6.41 | 31.4 | 6.38 | 31.1 |

For both raw water samples, the coagulation pH is below 6.5.

The two partial raw water analyses do not include hardness. For the January 2000 sample, the sum of the anions is 1.81 meq/l, so the divalent cations can be 1.81 meq/l at most. This is equivalent to a hardness of 91 mg/l. For the March 2000 sample, the maximum possible hardness is 101 mg/l. The water has a free carbon dioxide content of between 31 mg/l and 87 mg/l depending on the pH. According to the MENR Design Manual, the water will be extremely aggressive towards cement and iron products.

### 3.5.4 Flow metering

3.5.4.1 Bulk flow meters

The raw water flow to the water treatment works is not metered. There is a broken bulk flow meter on the rising main to the service reservoirs. There is also a broken meter on the outlet pipework from the service reservoirs. The two broken meters have been unserviceable for a number of years.

3.5.4.2 Consumer metering

The available billing records reproduced in Appendix 3 show that there are 754 active connections to the Webuye distribution system, not 1,280. Only 7 of these active connections have functional water meters. Bills for the remaining 747 connections are based on estimated consumptions.

### 3.5.5 System operation

Operations staff report that the reservoir outlet valves are opened at 6:00 a.m. each day, and that the two reservoirs empty within three to four hours. The valves are then closed and the reservoirs are refilled. At their nominal output, the clear water pumps are capable of delivering 1,968 $m^3/d$, but the unconventional mode of system operation limits the supply to less than 1,200 $m^3/d$. The District Water Office has confirmed that 1,200 $m^3/d$ is the current water production.

### 3.5.6 Facilities and equipment

The Divisional Water Office is housed in two permanent structures within town. There is no power supply or telephone at the offices. At the water treatment works site, there is a laboratory next to the clear water pump room, but this has only basic furniture and no laboratory equipment. There is no telephone at the treatment works site. While there is a power supply to the laboratory, staff have been unable to obtain fluorescent tubes for the light fittings.

The Divisional Water Office has no transport facilities.

## 3.6 LEVELS OF SERVICE

### 3.6.1 Major consumers

There is one metered connection in Webuye consuming more than 40 $m^3$ per month, and a further nineteen unmetered connections with estimated consumptions of over 40 $m^3$ per month. These twenty connections account for a monthly water consumption of 1,829 $m^3$, in the following charge bands:

**Table 3.2**
**Monthly consumptions for large consumers**

| **Charge band** | **Consumption ($m^3$/month)** |
|---|---|
| 0-10 $m^3$/month minimum charge band | 200 |
| 10-20 $m^3$/month band | 200 |
| 20-50 $m^3$/month band | 593 |
| 50-100 $m^3$/month band | 386 |
| 100-300 $m^3$/month band | 450 |
| Over 300 $m^3$/month band | 0 |
| Total | 1,829 |

### 3.6.2 Population served

The remaining 734 connections in Webuye are assumed to supply domestic consumers. The results of the 1999 census show Webuye had a population of 70,137 in 15,355 households. This gives a mean household size of 4.57. Therefore, approximately 3,355 people benefit from piped water supplies, or 4.78% of the town's population.

## 3.7 ON-GOING OR PLANNED EL NIÑO WORKS

The following works are being, or will be, carried out under the El Niño project:

- Fencing the intake site;
- Raising the weir wall at the intake;
- Duplication of the conventional clarifiers and filters;
- Rehabilitation of the existing conventional and "Struja" treatment plants;
- Construction of a chemical dosing house;
- Rehabilitation of staff housing at the water treatment works;
- Repair of the broken clear water pump and motor;
- Repair of the ten inch rising main where it crosses the stream below the treatment plant;
- Cleaning and painting the service reservoirs;
- Fencing the service reservoir site;
- Repair of sections of reticulation pipework;
- Provision of small tools.

## 3.8 OTHER WORKS AND PROJECTS

There are no other works or projects affecting the Webuye water supply system.

# 4 PROPOSED STRATEGY FOR WATER SUPPLY REHABILITATION

## 4.1 DEMAND/CONSUMPTION PROJECTIONS TO 2010

### 4.1.1 Population projections

As discussed in Section 2.6, the population of Webuye is projected to increase at 4.05% per annum to reach 108,500 in the year 2010. The projected population for the municipality is given in Table 4.1.

**Table 4.1**
**Population projection**

| Year | Population |
|---|---|
| 1999 | 70,137 |
| 2000 | 73,000 |
| 2001 | 76,000 |
| 2002 | 79,000 |
| 2003 | 82,200 |
| 2004 | 85,500 |
| 2005 | 89,000 |
| 2006 | 92,600 |
| 2007 | 96,400 |
| 2008 | 100,300 |
| 2009 | 104,300 |
| 2010 | 108,500 |

### 4.1.2 Water demand projections

4.1.2.1 <u>Unit water consumption</u>

Unit consumptions are taken from the then Ministry of Water Development Design Manual (1986).

4.1.2.2 <u>Levels of service</u>

It is assumed that the Government of Kenya achieves its goal of providing piped water to one hundred per cent of the urban population by the year 2010. It is further assumed that the classes of housing within Webuye will reflect the current broad levels of income.

**Table 4.2**
**Projected levels of service**

| Income level/housing class | Percentage in category |
|---|---|
| High | 13 |
| Medium | 38 |
| Low | 51 |

4.1.2.3 Domestic water demand

The domestic water demand projection for Webuye is shown in Table 4.3.

4.1.2.4 Institutional and commercial water demands

The estimated current institutional and commercial water demand is summarised below.

**Table 4.4**
**Institutional and commercial water demands**

| Activity | Nr | l/unit/d | total |
|---|---|---|---|
| **Commercial** | | | |
| Shops | 155 | 100 | 15,500 |
| Hotel low class (assume 20 beds each) | 100 | 50 | 5,000 |
| Hotel high class (assume 20 beds each) | 20 | 200 | 4,000 |
| Bars and restaurants | 10 | 500 | 5,000 |
| Garages | 5 | 500 | 2,500 |
| Total commercial | | | 32,000 |
| **Institutional** | | | |
| Sub-District Hospital (assume 200 beds) | 200 | 200 | 40,000 |
| Day schools | 15,000 | 5 | 75,000 |
| Dispensaries | 12 | 5,000 | 60,000 |
| Total institutional | | | 175,000 |
| **Industrial** | | | |
| Paper factory (own water supply) | | | 0 |
| Chemical factory (uses sulphuric acid, not water) | | | 0 |
| Total commercial, institutional and industrial demand | l/d | | 207,000 |
| | $m^3/d$ | | 207 |

### 4.1.3 Comparison of projected demand with system capacity

Table 4.3 compares the projected water demands with the capacities of the various system components.

**Table 4.3**
**Projected Water Demands and Current System Capacities**

| Year | Population | Income brackets | | Population | Demand rate lcd | Demand $m^3/d$ | Institutional demand $m^3/d$ | Total demand $m^3/d$ | Production capacity $m^3/d$ | Transmission capacity $m^3/d$ | Storage capacity $m^3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Status | % | | | | | | | | |
| **1999** | 70,137 | High | 13 | 9,118 | 250 | 2,279 | | | | | |
| | | Middle | 38 | 26,652 | 150 | 3,998 | 207 | **9,167** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 35,770 | 75 | 2,683 | | | | | |
| **2000** | 73,000 | High | 13 | 9,490 | 250 | 2,373 | | | | | |
| | | Middle | 38 | 27,740 | 150 | 4,161 | 215 | **9,541** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 37,230 | 75 | 2,792 | | | | | |
| 2001 | 76,000 | High | 13 | 9,880 | 250 | 2,470 | | | | | |
| | | Middle | 38 | 28,880 | 150 | 4,332 | 224 | **9,933** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 38,760 | 75 | 2,907 | | | | | |
| 2002 | 79,000 | High | 13 | 10,270 | 250 | 2,568 | | | | | |
| | | Middle | 38 | 30,020 | 150 | 4,503 | 233 | **10,325** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 40,290 | 75 | 3,022 | | | | | |
| 2003 | 82,200 | High | 13 | 10,686 | 250 | 2,672 | | | | | |
| | | Middle | 38 | 31,236 | 150 | 4,685 | 242 | **10,743** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 41,922 | 75 | 3,144 | | | | | |
| 2004 | 85,500 | High | 13 | 11,115 | 250 | 2,779 | | | | | |
| | | Middle | 38 | 32,490 | 150 | 4,874 | 252 | **11,175** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 43,605 | 75 | 3,270 | | | | | |
| 2005 | 89,000 | High | 13 | 11,570 | 250 | 2,893 | | | | | |
| | | Middle | 38 | 33,820 | 150 | 5,073 | 262 | **11,632** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 45,390 | 75 | 3,404 | | | | | |
| 2006 | 92,600 | High | 13 | 12,038 | 250 | 3,010 | | | | | |
| | | Middle | 38 | 35,188 | 150 | 5,278 | 273 | **12,103** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 47,226 | 75 | 3,542 | | | | | |
| 2007 | 96,400 | High | 13 | 12,532 | 250 | 3,133 | | | | | |
| | | Middle | 38 | 36,632 | 150 | 5,495 | 284 | **12,599** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 49,164 | 75 | 3,687 | | | | | |
| 2008 | 100,300 | High | 13 | 13,039 | 250 | 3,260 | | | | | |
| | | Middle | 38 | 38,114 | 150 | 5,717 | 296 | **13,109** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 51,153 | 75 | 3,836 | | | | | |
| 2009 | 104,300 | High | 13 | 13,559 | 250 | 3,390 | | | | | |
| | | Middle | 38 | 39,634 | 150 | 5,945 | 308 | **13,632** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 53,193 | 75 | 3,989 | | | | | |
| 2010 | 108,500 | High | 13 | 14,105 | 250 | 3,526 | | | | | |
| | | Middle | 38 | 41,230 | 150 | 6,185 | 320 | **14,181** | 3,200 | 1,968 | 960 |
| | | Low | 51 | 55,335 | 75 | 4,150 | | | | | |

The tabulated treatment capacity of 3,200 $m^3/d$ is the nominal plant capacity reported by the District Water Office. It includes the capacity of the intake and the treatment plant being constructed under the El Niño Emergency Project (ENEP).

The transmission capacity of 1,968 $m^3/d$ is that after the existing clear water pumps have been repaired under ENEP.

The tabulated equivalent storage capacity of 960 $m^3/d$ is calculated as the total storage volume of 1,200 $m^3$ divided by 1.25 to give the supply for which storage is equal to eighteen hours emergency capacity plus twelve hours balancing capacity.

## 4.2 PRELIMINARY DESIGN OF RECOMMENDED REHABILITATION OPTION

### 4.2.1 Raw water division

A chamber with 3 outlet weirs with crest lengths in the ratio 1.45:1.45:0.40 will correctly proportion the incoming flow between the two conventional plants and the "Spurja" unit. For a 1.2 m diameter chamber and 100 mm dividing walls, the correct weir lengths are 1.52 m, 1.52 m and 0.42 m.

### 4.2.2 Water chemistry and chemical dosing regime

4.2.2.1 <u>Coagulation and stabilisation</u>

In Section **Error! Reference source not found.**, it was shown that the coagulation pH is less than the minimum permissible value of 6.5. The pH and alkalinity can be raised by dosing soda ash. This will lower the dissolved carbon dioxide, but will not affect the hardness. The MENR Design Manual shows that water with a hardness of 70 mg/l and dissolved carbon dioxide of 9 mg/l will be only slightly aggressive to cement products. The calculated soda ash doses to achieve this value are shown below, together with the final pH.

**Table 4.5**
**Required soda ash dose**

| Temperature (°C) | 10 | | 15 | | 20 | | 25 | |
|---|---|---|---|---|---|---|---|---|
| Raw water pH and alkalinity | $Na_2CO_3$ | PH | $Na_2CO_3$ | pH | $Na_2CO_3$ | pH | $Na_2CO_3$ | pH |
| 6.5, 72 mg/l | 188.3 | 7.79 | 174.5 | 7.72 | 163.8 | 7.66 | 155.8 | 7.61 |
| 7.68, 70 mg/l | 56 | 7.42 | 55 | 7.37 | 54 | 7.32 | 54 | 7.30 |

The calculated soda ash dose to achieve stable product water is substantial, especially if the pH of raw water can be as low as 6.5. Accurate pH determinations are required to calculate the correct dose.

4.2.2.2 Chemical dosing for disinfection

To achieve a free chlorine residual, sufficient chlorine must be dosed to react with any dissolved ammonia, iron, manganese, etc. The required doses are:

- 7.6 g of chlorine to react with 1 g of ammonia;
- 0.54 g of chlorine to react with 1 g of ferrous iron, and
- 1.5 g of chlorine to react with 1 g of manganese.

The water sample taken in January 2000 contained 0.2 mg/l of ammonia, 0.02 mg/l of dissolved iron and 0.1 mg/l of dissolved manganese. To attain a free chlorine residual of 0.5 mg/l, the required dosing rate is 2.2 mg/l. Tropical chloride of lime (TCL) contains approximately 30% of available chlorine, giving a required dosing rate of 7.3 mg/l. Pure calcium hypochlorite contains 71.57% of available chlorine: commercial grades contain 70%, giving a required dosing rate of 3.12 mg/l.

### 4.2.3 Laboratory facilities

Laboratory equipment should be provided for routine determinations of temperature, turbidity, pH, alkalinity and chlorine residual.

### 4.2.4 Clear water pumps

The installed clear water pump capacity should be upgraded to match the total treatment plant capacity of 3,200 $m^3$/d or 133 $m^3$/hr. From the available 1:50,000 topographic mapping, the level at the water treatment plant is approximately 1,490 m AMSL and the level at the storage site is approximately 1,580 m AMSL. The static head from the treatment works site to the service reservoirs is therefore some 90 m.

A 10" steel pipe has an outside diameter of 273.05 mm and a wall thickness of 4.0 mm. Allowing 3 mm for a spun bitumen lining, the internal diameter is 259.05 mm. A flow of 133 $m^3$/hr in the pipe represents a flow velocity of 0.703 m/s and a friction slope of 2.79 m/km for the roughness size of 1 mm stipulated in the Ministry's design manual. The frictional head loss in 1,500 m of rising main is 4.2 m. Allowing 2 m for losses in the pump station pipework, the design pump head becomes 96.2 m.

A head of 96.2 m is too high for a DIN 24255 end-suction pump, but is feasible with an ISO 2858 standard chemical pump with bronze impeller running at two-pole speed. Pumps arranged in a one duty plus one standby configuration would have an efficiency of about 70%. A better solution is to use multi-stage pumps running at four-pole speed. One duty plus one standby pump would have an efficiency of about 77%.

### 4.2.5 Metering of treated water production

A 150 mm nominal bore meter complying with Class B requirements is rated for a continuous flow of 150 $m^3$/hr, so a 200 mm nominal bore meter is required for a pump output of 175 $m^3$/hr. This size meter will be accurate to ±2% from 50 $m^3$/hr to 500 $m^3$/hr.

### 4.2.6 Rising main

As shown in Section 4.2.2 above, the treated water being produced now is extremely aggressive to steel products, yet the rising main has conveyed this water for the past twenty-eight years. The main should be replaced.

### 4.2.7 Storage

The combined capacity of the existing service reservoirs is 1,200 $m^3$/d. The MENR Design Manual requires a balancing storage volume of 12 hours and an emergency storage volume of 18 hours for systems supplied by pumping. For a plant output of 3,200 $m^3$/d, the required storage volume is therefore 4,000 $m^3$ or 2,800 $m^3$ more than the existing capacity. An additional 3,000 $m^3$ of storage is proposed.

### 4.2.8 Distribution

4.2.8.1 <u>Main reservoir outlet pipework</u>

The main outlet from the service reservoirs is an 8" asbestos cement main that was laid in 1972. As shown in Section 4.2.2 above, the treated water being produced now is extremely aggressive to cement products, yet the pipeline has conveyed this water for the past twenty-eight years. The pipeline should be replaced.

Operations staff report that the service reservoirs empty in 3 to 4 hours once the valve to the distribution system is opened. Draining 1,200 $m^3$ of water in 3 hours represents a peak flow of some 400 $m^3$/hr. This flow in an 8" asbestos cement main gives a velocity of 3.54 m/s and a friction slope of 55.5 m/km for a roughness size of 0.1 mm. The length of the outlet pipe is some 450 m, so the head loss is 25 m. This is excessive.

If the pipe is replaced with a 315 mm Class B uPVC pipe, the velocity is reduced to 1.53 m/s and the friction slope to 7.1 m/km. The total length of 8" asbestos cement pipe that has conveyed aggressive water is 1,270 m, and it is proposed to replace the entire length with 315 mm uPVC pipe.

#### 4.2.8.2 Distribution network within Webuye

The Bungoma District Water Office has indicated that the entire distribution system, comprising some 30 km of pipe, should be replaced.

#### 4.2.8.3 Bulk metering of outflow from the reservoirs

The peak outflow from the service reservoirs will be some 350 $m^3$/hr to 400 $m^3$/hr. To measure sustained flows of this magnitude would require a 250 mm Class B meter, but this would only be accurate to ±2% for flows above 80 $m^3$/hr. This would be unable to measure off-peak flows accurately, so we do not recommend replacing the meter on the reservoir outlet. The meter should be removed to reduce head losses in the outlet pipework.

#### 4.2.8.4 Consumer meters

The majority of active consumers do not have functioning water meters. We recommend the installation of functional consumer meters.

## 4.3 COSTING OF RECOMMENDED REHABILITATION PLAN

An indicative budget for rehabilitating the existing Webuye water supply system is given in Table 4.6 below.

**Table 4.6**
**Rehabilitation costs**

| Description | Unit | Quantity | Rate (Kshs) | Amount (KShs) |
|---|---|---|---|---|
| **Intake and raw water main** | | | | |
| Construct splitter box to apportion flow between plants | Sum | | | 240,000 |
| **Subtotal** | | | | **240,000** |
| **Treatment plant** | | | | |
| Install dosers for soda ash | nr | 6 | 100,000 | 600,000 |
| Provide laboratory equipment and consumables | Sum | | | 4,500,000 |
| New clear water pumps | nr | 2 | 4,800,000 | 9,600,000 |
| 250 mm steel rising main | m | 1,500 | 9,375 | 14,062,500 |
| **Subtotal** | | | | **28,762,500** |
| **Storage** | | | | |
| Construct 2,000 $m^3$ reservoir | Sum | | | 6,250,000 |
| **Subtotal** | | | | **6,250,000** |
| **Distribution system** | | | | |
| 315 mm uPVC reservoir outlet | m | 1,270 | 5,900 | 7,493,000 |
| Distribution pipework | m | 30,000 | 1,600 | 48,000,000 |
| New consumer meters (replacement and stock) | nr | 2,000 | 3,000 | 6,000,000 |
| **Subtotal** | | | | **61,493,000** |
| **Logistical facilities and equipment** | | | | |
| New office and laboratory facilities | $m^2$ | 400 | 25,000 | 10,000,000 |
| 4WD twin-cab pickups | nr | 1 | 2,500,000 | 2,500,000 |
| 4WD standard vehicles | nr | 1 | 1,500,000 | 1,500,000 |
| Motorcycles for line patrols, meter readings, etc. | nr | 4 | 250,000 | 1,000,000 |
| Multi-geared bikes | nr | 2 | 25,000 | 50,000 |
| Desk top computer setups | nr | 5 | 200,000 | 1,000,000 |
| Printers | nr | 2 | 100,000 | 200,000 |
| Licensed standard computer software | Sum | | | 1,000,000 |
| Standard office equipment, furniture and fittings | Sum | | | 1,500,000 |
| **Subtotal** | | | | **18,750,000** |
| **Overall Total** | | | | **115,495,500** |
| Add 20% P&G | | | | 23,099,100 |
| Sub-total | | | | 138,594,600 |
| Add 15% Contingencies | | | | 20,789,190 |
| Sub-total | | | | 159,383,790 |
| Add 20% consultancy design fees | | | | 31,876,758 |
| **GRAND TOTAL** | | | | **191,260,548** |

## 4.4 FUTURE EXPANSION OF WATER SUPPLIES

### 4.4.1 General

The design horizon for expansion works is the year 2010.

### 4.4.2 Adequacy of source

Table 2.4 of this report shows that the available yield from the Nzoia River is some 193,000 $m^3/d$. Table 4.3 shows a projected water demand of 14,181 $m^3/d$ in the year 2000. The existing water source is sufficient to meet projected demands for the foreseeable future.

### 4.4.3 Intake and raw water main

The existing intake and raw water main are sized for 3,200 $m^3/d$. A new raw water main will be required to meet the projected demands. The main is provisionally sized at 500 mm, giving a flow velocity of 0.863 m/s when conveying 14,181 $m^3/d$. The preferred pipe material for engineering and economic reasons is steel.

### 4.4.4 Water treatment plant

New treatment units will be required with a total capacity of some 11,000 $m^3/d$. The land requirement for horizontal flow clarifiers of such a capacity is some 454 $m^2$. This presents obvious difficulties at the existing treatment site. It is assumed that the additional clarifiers will be upward flow units and filters will be rapid gravity.

Sludge generation rates at a works with a total capacity of some 14,200 $m^3/d$ will become a significant environmental issue.

### 4.4.5 Transmission

Assuming the clear water pumps and rising main installed during the rehabilitation phase are retained, a new transmission system with a capacity of 11,000 $m^3/d$ will be required. A 400 mm steel rising main is proposed for pumping treated water to the town storage site.

### 4.4.6 Storage

For an average daily demand of 14,181 $m^3/d$, the required storage volume to balance supply and demand is 7,091 $m^3$, with a further 10,636 $m^3$ required as emergency storage. Constructing such large tanks at the existing storage site presents obvious difficulties. It is assumed that a second 3,000 $m^3$ tank is constructed, and that the emergency storage requirement can be relaxed if a standby generator is installed at the water treatment plant.

### 4.4.7 Distribution

A network analysis of the entire service area will be required using topographical survey information, population density and settlement data and the physical development plan for the town. The results of the analysis will identify the optimum elevation for elevated storage and sizes of primary, secondary and tertiary distribution pipelines.

In order to provide indicative budgetary estimates for expanding the distribution system, allowance is made for reticulating an additional area of 125 $km^2$. Assuming that each square kilometre of the service area contains 10 km of distribution pipes with a size greater than 50 mm, then 1,250 km of additional pipelines are required to serve the municipal area.

## 4.5 COST OF EXPANSION WORKS

An indicative cost estimate for expanding water supplies in Webuye is given in Table 4.7.

The cost of reticulating the town is extremely high. The results of the 1999 census show that large areas of Maraka have population densities less than five hundred people per square kilometre. This is equivalent to 5 people (or approximately one family) per hectare. At current tariffs, it is not economically viable for a water undertaker to provide such sparsely settled areas with piped water. The expansion of the distribution system should instead target the more densely settled areas. The importance of planned urban development to the economic provision of services cannot be over-emphasised.

**Table 4.7**
**Estimated cost of expanding water supplies**

| Description | Unit | Quantity | Rate | Amount (KShs) |
|---|---|---|---|---|
| **Intake, treatment and transmission** | | | | |
| 500 mm raw water main | m | 300 | 20,000 | 6,000,000 |
| 11,000 $m^3/d$ treatment plant | Sum | | | 130,000,000 |
| Clear water pumps | nr | 2 | 7,000,000 | 14,000,000 |
| 400 mm clear water main | m | 1,500 | 15,000 | 22,500,000 |
| subtotal | | | | 172,500,000 |
| **Storage** | | | | |
| 11,000 $m^3$ reservoir | Sum | | | 55,000,000 |
| subtotal | | | | 55,000,000 |
| **Distribution** | | | | |
| uPVC distribution pipework n.e. 150 mm | m | 1,250,000 | 1,600 | 200,000,000 |
| Consumer meters | nr | 14,000 | 3,000 | 42,000,000 |
| subtotal | | | | 242,000,000 |
| Overall Total | | | | 469,500,000 |
| Add 20% P&G | | | | 93,900,000 |
| Sub-total | | | | 563,400,000 |
| Add 15% Contingencies | | | | 84,510,000 |
| Sub-total | | | | 647,910,000 |
| Add 20% consultancy design fees | | | | 129,582,000 |
| **GRAND TOTAL** | | | | **777,492,000** |

## 4.6 O&M COSTS AFTER REHABILITATION

### 4.6.1 General

Following commissioning of the ENEP treatment plant extensions, water production capacity will exceed water sales and the plant will not be operating at full capacity. Chemical and power costs are dependent on the quantities of water being produced, so it is necessary to develop water sales and production forecasts to assess these costs.

### 4.6.2 Water sales and production forecasts

4.6.2.1 <u>Existing connections and unit consumptions</u>

There are only 754 active connections to the Webuye water supply system, only seven of which have functioning meters. There are also 933 inactive accounts and 419 dead accounts. In June 2000, the billed "sales" were 32,987 $m^3$, or 1,100 $m^3/d$. This implies unaccounted for water is only 8.4% of production: an unrealistically low figure for a system nearly thirty years old.

It is suspected that estimated "sales" are grossly overstated. Table 3.2 gives the reported consumptions for the twenty connections consuming more than 40 $m^3$/month. The billed "sales" for the remaining 734 active connections represents 1,415 litres per connection per day or 310 litres per head per day. This is unrealistically high given the housing stock in Webuye.

For developing a water sales forecast, the consumption pattern given in Table 3.2 is applied to the 20 connections consuming more than 40 $m^3$/month. The remaining 734 domestic connections are assumed to be as presented in Table 4.8.

**Table 4.8**
**Assumed domestic connections**

| Housing category | Number of connections | Household size | Per capita consumption (lcd) | Consumption per household ($m^3$/month) |
|---|---|---|---|---|
| High class housing | 100 | 4.57 | 250 | 34.75 |
| Medium class housing | 500 | 4.57 | 150 | 20.85 |
| Low class housing | 134 | 4.57 | 75 | 10.43 |

4.6.2.2 Future connections

For developing the water sales forecast, it is assumed that:

600 of the inactive accounts become legally reconnected to the distribution system during the rehabilitation phase.
Thereafter, 120 new connections are made per year: 84 to low class housing and 36 to medium class housing.

4.6.2.3 Water sales forecasts

The water sales forecast is given in Table 4.9.

4.6.2.4 Allowance for unaccounted for water

It is assumed that once all legal consumers are metered, the volume of unaccounted for water will decline to 20% of water production.

4.6.2.5 Water production forecasts

The forecast of water production requirements is also given in Table 4.9.

**Table 4.9**
**Webuye Water Sales and Production Projections**

**Domestic connections by housing class**

| Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High class connections @ 250 lcd (34.75 $m^3$/m) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Medium class connections @ 250 lcd (20.85 $m^3$/m) | 500 | 500 | 1,100 | 1,136 | 1,172 | 1,208 | 1,244 | 1,280 | 1,316 | 1,352 | 1,388 |
| Low class connections @ 75 lcd (10.43 $m^3$/m) | 134 | 134 | 134 | 218 | 302 | 386 | 470 | 554 | 638 | 722 | 806 |

**Domestic sales within charge bands ($m^3$ p.a.)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 $m^3$/month minimum charge band | 88,080 | 88,080 | 160,080 | 174,480 | 188,880 | 203,280 | 217,680 | 232,080 | 246,480 | 260,880 | 275,280 |
| 10-20 $m^3$/month band | 72,691 | 72,691 | 144,691 | 149,445 | 154,198 | 158,952 | 163,705 | 168,459 | 173,212 | 177,966 | 182,719 |
| 20-50 $m^3$/month band | 22,800 | 22,800 | 28,920 | 29,287 | 29,654 | 30,022 | 30,389 | 30,756 | 31,123 | 31,490 | 31,858 |

**Institutional sales within charge bands ($m^3$ p.a.)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 $m^3$/month minimum charge band | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 |
| 10-20 $m^3$/month band | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 |
| 20-50 $m^3$/month band | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 | 3,480 |
| 50-100 $m^3$/month band | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 |
| 100-300 $m^3$/month band | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 |
| Over 300 $m^3$/month band | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Total sales within charge bands ($m^3$ p.a.)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-10 $m^3$/month minimum charge band | 89,280 | 89,280 | 161,280 | 175,680 | 190,080 | 204,480 | 218,880 | 233,280 | 247,680 | 262,080 | 276,480 |
| 10-20 $m^3$/month band | 73,891 | 73,891 | 145,891 | 150,645 | 155,398 | 160,152 | 164,905 | 169,659 | 174,412 | 179,166 | 183,919 |
| 20-50 $m^3$/month band | 26,280 | 26,280 | 32,400 | 32,767 | 33,134 | 33,502 | 33,869 | 34,236 | 34,603 | 34,970 | 35,338 |
| 50-100 $m^3$/month band | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 | 3,408 |
| 100-300 $m^3$/month band | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 | 5,040 |
| Over 300 $m^3$/month band | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 197,899 | 197,899 | 348,019 | 367,540 | 387,061 | 406,581 | 426,102 | 445,623 | 465,143 | 484,664 | 504,185 |

**Production requirements**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Daily sales ($m^3$/d) | 542 | 542 | 953 | 1,007 | 1,060 | 1,114 | 1,167 | 1,221 | 1,274 | 1,328 | 1,381 |
| Losses at 20% of production ($m^3$/d) | 136 | 136 | 238 | 252 | 265 | 278 | 292 | 305 | 319 | 332 | 345 |
| Daily water production ($m^3$/d) | 678 | 678 | 1,192 | 1,259 | 1,326 | 1,392 | 1,459 | 1,526 | 1,593 | 1,660 | 1,727 |

### 4.6.3 Power tariffs and costs

4.6.3.1 Tariffs

Power charges are calculated using the tariffs and levies prevailing in December 2000. These are shown in Table 4.10.

**Table 4.10**
**KPLC power tariffs**

| **Charge band** | **A1** | **B1** | **B2** |
|---|---|---|---|
| Monthly consumption not exceeding (kWh) | 7,000 | 100,000 | 100,000 |
| Supply voltage (V) | 415 | 415 | 11,000 |
| Monthly standing charge | 150.00 | 600.00 | 2,000.00 |
| Monthly maximum demand charge per kVA | 0.00 | 300.00 | 200.00 |
| High rate tariff per kWh | 6.70 | 6.10 | 5.50 |
| Low rate tariff per kWh | 6.70 | 3.75 | 3.25 |
| Fuel cost adjustment per kWh | 4.07 | 4.07 | 4.07 |
| Forex adjustment per kWh | 0.16 | 0.16 | 0.16 |
| ERB levy per kWh | 0.03 | 0.03 | 0.03 |
| REP levy at 5% on high rate tariff per kWh | 0.3350 | 0.3050 | 0.2750 |
| REP levy at 5% on low rate tariff per kWh | 0.3350 | 0.1875 | 0.1625 |
| VAT at 18% on high rate tariff per kWh | 1.2060 | 1.0980 | 0.9900 |
| VAT at 18% on low rate tariff per kWh | 1.2060 | 0.6750 | 0.5850 |
| Total high rate tariff per kWh | 12.5010 | 11.763 | 11.025 |
| Total low rate tariff per kWh | 12.5010 | 8.8725 | 8.2575 |

4.6.3.2 Running load at Webuye treatment plant

The total running load at Webuye water treatment plant is calculated for the clear water pump and lighting and small power at the treatment plant and adjacent staff housing. This is estimated to be 61 kVA, made up as follows.

**Table 4.11**
**Running load at treatment plant**

| Item | One clear water pump | Lighting and small power, say | Total running load |
|---|---|---|---|
| Flow ($m^3/hr$) | 133 | | |
| Head (m) | 96 | | |
| Efficiency | 76% | | |
| Power (kW) | 45.9 | 9.0 | 48.9 |
| Power (kVA) at cost factor F = 0.9 | 51.0 | 10.0 | 61.0 |

At a daily water production of 1,192 $m^3/d$ in 2002, the monthly power consumption of the clear water pump is 12,341 kWh, so charge band B1 applies.

4.6.3.3 Power costs

To develop power cost estimates, it is assumed that the clear water pump is started at 8:00 am each day and runs until the service reservoirs have been replenished.

**Table 4.12**
**Annual power costs at Webuye water treatment plant**

| Year | Daily water production ($m^3/d$) | Hours run by pump per day | Annual power costs (Kshs) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Standing charge | Maximum demand charge | Pump kWh charge | Small power kWh charge | Total power cost |
| 2000 | 678 | 5.10 | 7,200 | 219,600 | 968,979 | 231,858 | 1,427,636 |
| 2001 | 678 | 5.10 | 7,200 | 219,600 | 968,979 | 231,858 | 1,427,636 |
| 2002 | 1,192 | 8.96 | 7,200 | 219,600 | 1,683,528 | 231,858 | 2,142,186 |
| 2003 | 1,259 | 9.46 | 7,200 | 219,600 | 1,775,630 | 231,858 | 2,234,288 |
| 2004 | 1,326 | 9.97 | 7,200 | 219,600 | 1,867,732 | 231,858 | 2,326,390 |
| 2005 | 1,392 | 10.47 | 7,200 | 219,600 | 1,959,834 | 231,858 | 2,418,492 |
| 2006 | 1,459 | 10.97 | 7,200 | 219,600 | 2,051,936 | 231,858 | 2,510,594 |
| 2007 | 1,526 | 11.47 | 7,200 | 219,600 | 2,144,038 | 231,858 | 2,602,696 |
| 2008 | 1,593 | 11.98 | 7,200 | 219,600 | 2,236,140 | 231,858 | 2,694,798 |
| 2009 | 1,660 | 12.48 | 7,200 | 219,600 | 2,328,242 | 231,858 | 2,786,900 |
| 2010 | 1,727 | 12.98 | 7,200 | 219,600 | 2,420,344 | 231,858 | 2,879,001 |

### 4.6.4 Chemical costs

Chemical costs are estimated for the current aluminium sulphate dose of 70 mg/l and a soda ash dose of 55 mg/l. the estimated chemical costs are shown in Table 4.13.

**Table 4.13**
**Estimated chemical costs**

| Chemical | Cost Kshs/kg | Dosage (mg/l) | Cost (Kshs/m$^3$) |
|---|---|---|---|
| Aluminium sulphate | 28 | 70 | 1.79 |
| Soda ash | 7 | 55 | 0.39 |
| Calcium hypochlorite | 245 | 3.2 | 0.78 |
| Total | | 39 | 2.96 |

The annual chemical costs are given below for the forecast water production.

**Table 4.14**
**Annual chemical costs**

| Year | Daily water production (m$^3$/d) | Annual chemical costs (Kshs per annum) |
|---|---|---|
| 2000 | 678 | 732,228 |
| 2001 | 678 | 732,228 |
| 2002 | 1,192 | 1,287,672 |
| 2003 | 1,259 | 1,359,898 |
| 2004 | 1,326 | 1,432,125 |
| 2005 | 1,392 | 1,504,351 |
| 2006 | 1,459 | 1,576,577 |
| 2007 | 1,526 | 1,648,804 |
| 2008 | 1,593 | 1,721,030 |
| 2009 | 1,660 | 1,793,257 |
| 2010 | 1,727 | 1,865,483 |

# 5 EXISTING WASTEWATER DISPOSAL AND SANITATION CONDITIONS

## 5.1 SANITATION SYSTEM

### 5.1.1 The Municipal Sewerage System

5.1.1.1 Inventory of the existing sewerage system

Webuye has a waterborne sewerage system that was constructed in 1974. The system covers about 2 $km^2$ of the municipal area while the water supply system covers about 10.4 $km^2$. Figure 5.1 shows the extent of the sewerage. The system serves the following areas:

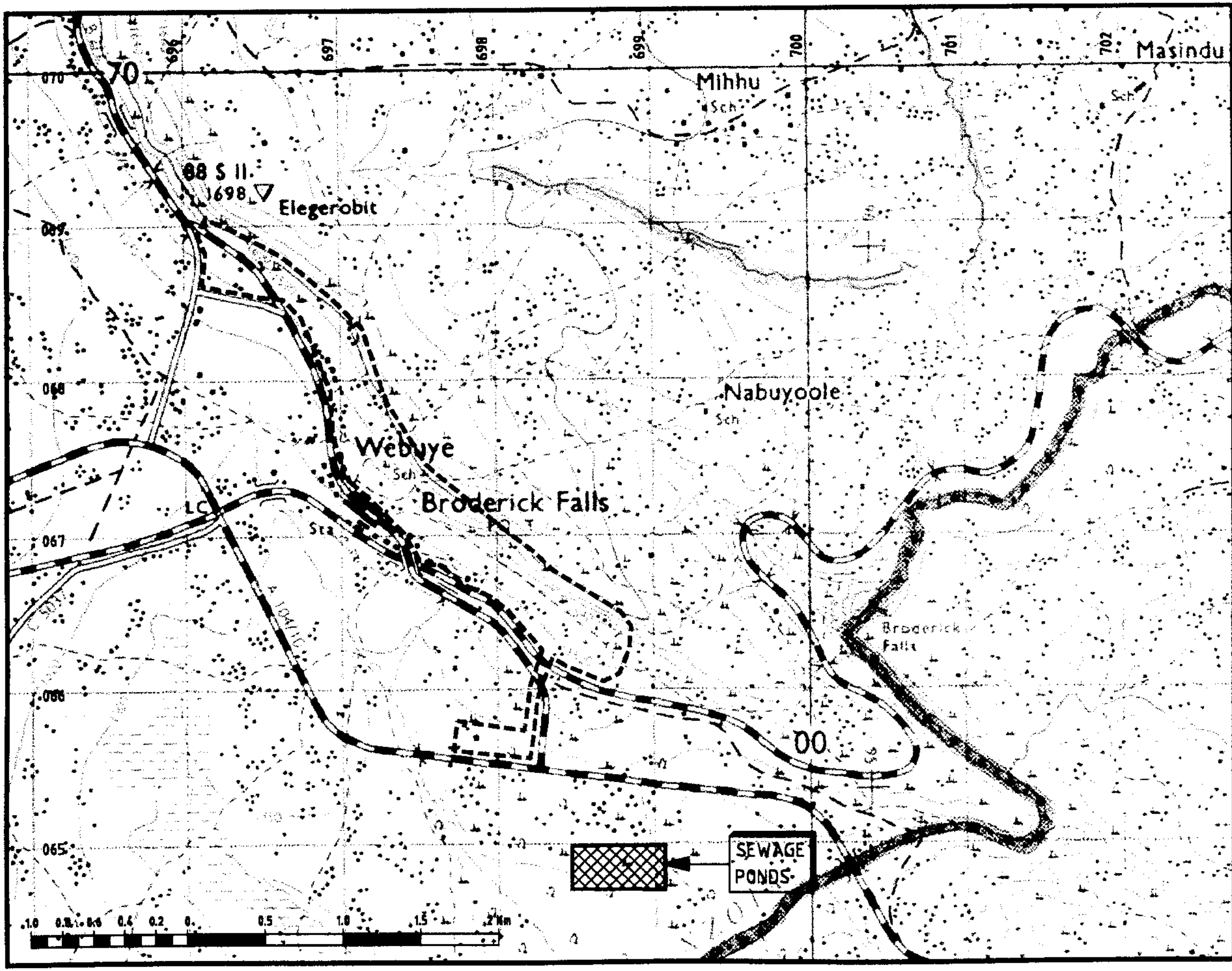
- Guest House Estate.
- Town Hall.
- The town's commercial centre.
- The two National Housing Corporation estates.
- Chocolate Estate.
- The site and service area adjacent to the A104.

This sewer network serves about 7% of the Municipal population though 1,100 connections while the rest is served by septic tanks and pit latrines.

As reported in the 1998 Aftercare Study, about 40% of the sewers are 100 mm and 150 mm diameter. Unfortunately, Webuye Municipal Council has no drawings of the sewerage system and has no records of the actual sewer sizes in the town.

5.1.1.2 Condition of the existing sewerage system

The sewers are in good structural conditions and no incidence of collapse has been reported. However, the main problem with the sewer network is the frequent blockages of the small size sewers. The council does not keep record of the sewer blockages.




NORTH

LEGEND

SEWER SERVED AREA

Client

JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa

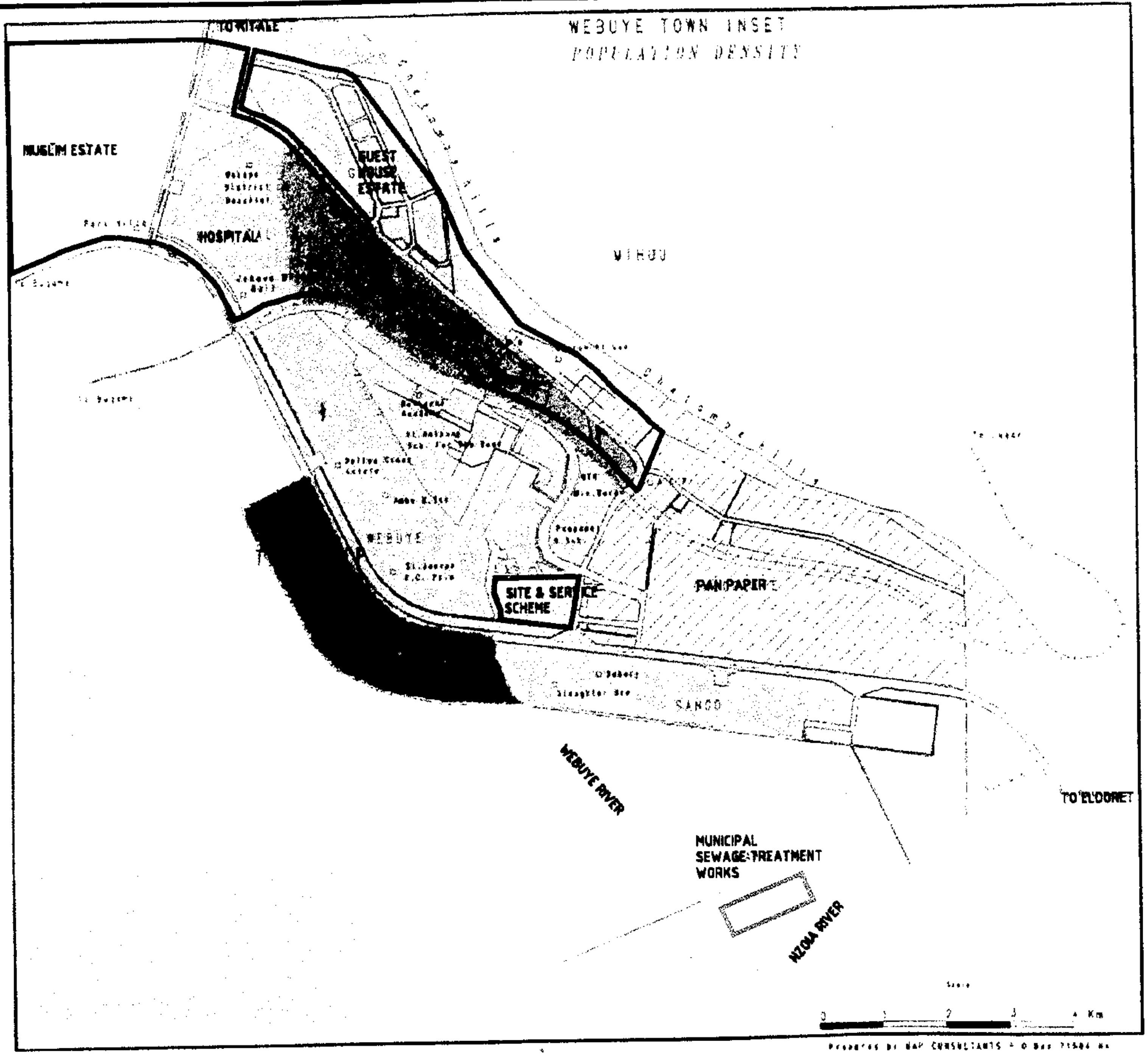
Project Title

TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title

WEBUYE TOWN AREA COVERED BY THE EXISTING SEWERAGE SCHEME

| Date | Fig. No. |
|---|---|
| JAN 2001 | 5.1 |




NORTH

LEGEND
EXISTING SEWERAGE COVERAGE
PROPOSED SEWERAGE COVERAGE
SEWAGE TREATMENT WORKS

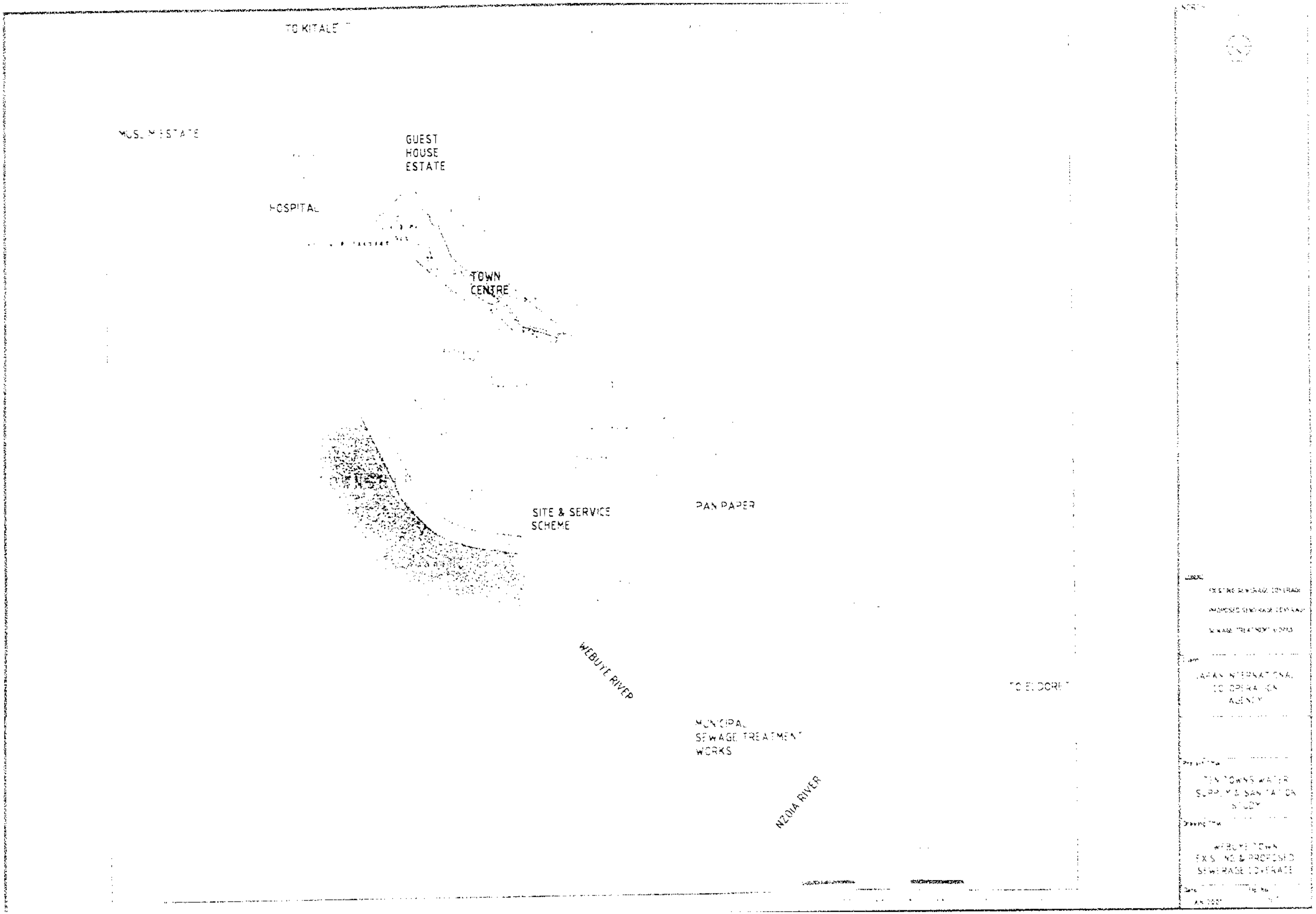
Client
JAPAN INTERNATIONAL CO-OPERATION AGENCY

GIBB Eastern Africa

Project Title
TEN TOWNS WATER SUPPLY & SANITATION STUDY

Drawing Title
WEBUYE TOWN EXISTING & PROPOSED SEWERAGE COVERAGE

| Date | Fig. No. |
|---|---|
| JAN 2001 | 5.1 |



TO KITALE
GUEST
HOUSE
ESTATE
HOSPITAL
TOWN
CENTRE
SITE & SERVICE
SCHEME
PAN PAPER
WEBUYE RIVER
NZOIA RIVER

### 5.1.2 Municipal Sewage Treatment Plant

#### 5.1.2.1 Inventory of the sewage treatment plant

The sewerage system discharges to a central sewage treatment plant comprising of two waste stabilisation ponds on the southern edge of the town. The system was constructed in 1974, two years after the construction of the water supply system. Effluent from the ponds is discharged into the Nzoia River.

The ponds dimensions are:

- First pond - area of 18,687 $m^2$ and a water depth of 1.2m
- Second pond - area of 5,456 $m^2$ and a water depth of 1.2m.

There is no inlet works at the treatment plant for removal of screenings and grit.

#### 5.1.2.2 Capacity of the existing treatment plant

There are no design data for the existing treatment plant and the capacity has been estimated on the basis of the design manual for waste stabilisation ponds.

The existing two ponds will function as facultative ponds with BOD and suspended solids reduction as the main function. According to a design manual for waste stabilisation ponds in East Africa by Mara et al, the maximum BOD surface loading rate for facultative ponds at a temperature of 18°C is 217kg/ha/d. This implies that the estimated BOD load to the sewage treatment plant is 406 kg/d on the basis of the first pond. The WHO Report 9 recommends a per capita BOD load contribution of about 48 g/ca/d in Kenya. On the basis of the per capita water demand recommended in the Ministry of Water design Manual and the population distribution in Chapter 2 of this report, the average water consumption in Webuye is some 140 lcd. With a sewage reduction factor of 0.8, the maximum flow to the treatment plant into order to maintain facultative environment in the first pond would be 947$m^3$/d. This results in retention periods of 24 and 7 days for the first and second pond respectively.

#### 5.1.2.3 Current sewage flows to the treatment plant

There is no facility for flow measurements at the existing sewage treatment plant. The current sewage connection has been used to estimate the sewage flows to the treatment plant.

The 1,100 sewer connections are mainly for individual households. With a household size of 4.57 persons as elaborated in Chapter 2 and assuming one connection per household, the estimated sewered population is 5,027. This sewered population is mainly comprised of low and medium income levels. The current estimated wastewater flow to the sewage treatment works at per capita sewage generation rate of 112 l/d is about 563 $m^3/d$.

5.1.2.4 Condition of the existing treatment plant

Due to lack of an inlet works for removal of screenings and grit there is high rate accumulation of sludge in the two ponds. A small chamber, which was meant to be a screening chamber, has been abandoned due to poor access for operation. The waste stabilisation ponds were reportedly desludged in 1979, but have not been cleaned since. The ponds are now full of sludge.

There are no scum boards at the outlet of both ponds and there is high tendency for algae and floating debris to be discharged into the recipient watercourse.

The site is not fenced and vehicular access to the site is not possible.

5.1.2.5 Effluent quality

There is no regular effluent sampling to monitor the system performance.

The capacity of these ponds to effectively remove BOD to the design level has been greatly reduced by the high sludge accumulation. These ponds were designed with a shallow depth and no allowance was made for any sludge storage. The BOD removal is dependent on the actual retention time. However, on the basis of the maximum allowable BOD loading to the first pond and assuming that there is no sludge accumulation, the anticipated filtered BOD concentration in the final effluent will be less than 20 mg/l. However, due to the high reduction of the effective pond volume it is unlikely that this will be achieved.

Using a flow of 947$m^3/d$ and faecal coliform in the raw sewage of about $4x10^7$ FC/100 ml and assuming that there is no sludge accumulation in both ponds, the coliform level in the final effluent is estimated to be over 35,000 FC/100 ml. This greatly exceeds the required level of 1,000 FC/100 ml for discharge to a watercourse. The situation is worsened by the high sludge accumulation.

The pathogen removal in these ponds is poor and additional ponds are required to reduce faecal coliform counts to acceptable levels.

### 5.1.3 Pan Paper's Wastewater Treatment

Pan Paper, the major industry in the town, operates their own system of aerated waste stabilisation ponds. The effluent BOD from the paper factory is reportedly 85 mg/l. Effluent is discharged into the Nzoia River upstream from the municipal wastewater treatment plant.

## 5.2 SEWERAGE SYSTEM (O&M)

Webuye Municipal Council is responsible for the operation and maintenance of the municipal sewerage system. Four staff are responsible for clearing blockages when they occur. The maintenance staff have sewer rods and access to transport vehicles, but do not have mechanical equipment for maintenance of the sewer network.

A sewerage levy of Ksh 60 per month is added to water bills. The revenue is collected by the Ministry of Environment and Natural Resources. The payment is made at local administrative offices.

## 5.3 SEWAGE TREATMENT WORKS (O&M)

The four sewer maintenance staff are responsible for maintenance of the sewage treatment plant.

Webuye Municipal Council have basic equipment for maintenance of sewage treatment plant like slashers, wheelbarrows etc but does not have access to suitable equipment for desludging the ponds. They have not been desludged since 1979.

There is no flow measuring device at the treatment plant and effluent sampling to assess the system performance is rarely done by staff from the Ministry of Environment and Natural Resources at Kakamega. Lack of properly equipped laboratory has been the main drawback in monitoring the system performance. Sample analysis results obtained from the monitoring team for 9 March 2000 were unrealistic for domestic sewage, reflecting lack of proper monitoring equipment.

## 5.4 OTHER DISPOSAL FACILITIES

Premises that are not connected to the municipal sewerage system are served by septic tanks or pit latrines. The council does not own a vacuum tanker, but hires a suitable vehicle from Eldoret, Busia or Kitale when required. Septic tank contents are discharged into the municipal sewer system as vehicular access to the waste stabilisation ponds is difficult.

## 5.5 ON-GOING OR PLANNED EL NINO WORKS

No improvements to the sewerage system are being carried out under the ongoing El Niño project.

## 5.6 OTHER WORKS AND PROJECTS

Webuye Municipal Council has an Environment Development Plan. This plan includes extensions to the municipal sewerage system to serve areas to the west including the District Hospital, Muslim Estate and the town's main hotel. However, the council lacks the funds to implement this plan.

## 5.7 SUMMARY OF SHORTCOMINGS AND PRELIMINARY RECOMMENDATIONS FOR REHABILITATION

The main shortcoming with the present sanitation system is the poor condition of the waste stabilisation ponds. Due to the high sludge accumulation in both ponds, the overall performance of the ponds has been reduced substantially. The final effluent from the last pond does not meet the required effluent discharge standard to the watercourse, so remedial measures are required. Details of the rehabilitation works are detailed in Chapter 6 and summarised in Table 5.1.

**Table 5.1**
**Schedule of rehabilitation works**

| Item | Unit | Ref | Component | Repairs needed | Comments /recommendations |
|---|---|---|---|---|---|
| 1 | Sewage treatment plant | 1.1. | Existing ponds | Desludging | To attain the effective volume of the pond |
| | | 1.2 | Ponds outlets | Install scum boards | To reduce outflow of algae and floating debris |
| | | 1.3 | Inlet works | Construct a new inlet works | Removal of screenings and grit before discharge to first pond |
| | | 1.4 | Polishing ponds | Construct maturation ponds | Reduce the faecal coliform to acceptable standards |
| | | 1.5 | Site | Fence the site | Ensure safety and prevent land grabbing. |
| | | 1.6 | Access road | Gravel the access road | Improve accessibility |