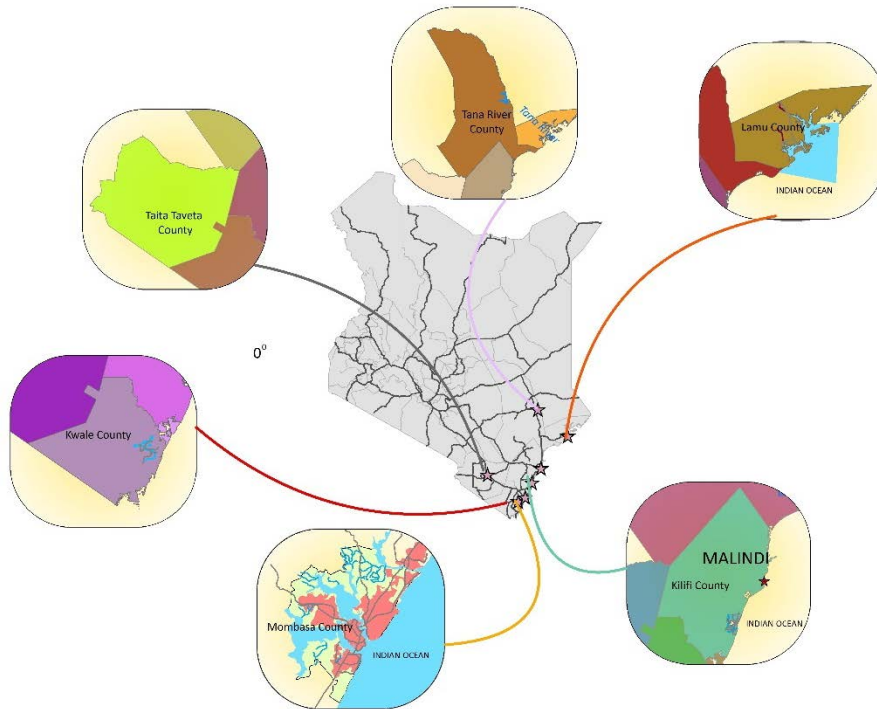# REPUBLIC OF KENYA

# COAST WATER SERVICES BOARD

## WATER AND SANITATION SERVICE IMPROVEMENT PROJECT – ADDITIONAL FINANCING (WaSSIP - AF)



## Consulting Services for Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region
## Contract No. CWSB/WaSSIP-AF/C/10/2012

### FINAL WASTEWATER MASTER PLAN REPORT FOR KILIFI TOWN

### VOLUME 1: MASTER PLAN MAIN REPORT

**MIBP**
**+PARTNERS**
**CONSULTING ENGINEERS**

In Association with:

CES
Consulting Engineers
Salzgitter GmbH

BOSCH
HOLDINGS

**MARCH 2017**

# "DOCUMENT CONTROL"

## WATER AND SANITATION SERVICE IMPROVEMENT PROJECT – ADDITIONAL FINANCING (WaSSIP – AF)

## Wastewater Master Plan for Mombasa and Selected Towns within the Coast Region

### EMPLOYER:

## Coast Water Services Board
## (CWSB)

**MIBP +PARTNERS CONSULTING ENGINEERS**

**CES Salzgitter GmbH**

**BOSCH HOLDINGS**

**DOCUMENT TITLE:**    **FINAL MASTER PLAN REPORT– KILIFI TOWN**
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# WATER AND SANITATION SERVICE IMPROVEMENT PROJECT – ADDITIONAL FINANCING (WaSSIP – AF)

# Wastewater Master Plan for Mombasa and Selected Towns within the Coast Region

## FINAL MASTER PLAN REPORT– KILIFI TOWN

## TABLE OF CONTENTS

## EXECUTIVE SUMMARY

## LIST OF FIGURES

# LIST OF TABLES

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| CES | - | Consulting Engineers Salzgitter GmbH |
| CWSB | - | Coast Water Services Board |
| DWF | - | Dry Weather Flow |
| EIA | - | Environmental Impact Assessment |
| EA | - | Environmental Audit |
| ESIA | - | Environmental & Social Impact Assessment |
| GoK | - | Government of Kenya |
| IDA | - | International Development Association |
| M&E | - | Mechanical & Electrical |
| MWI | - | Ministry of Water and Irrigation |
| MIBP | - | Mangat, I.B. Patel & Partners |
| KIMAWASCO | - | Kilifi Mariakani Water and Sanitation Company Ltd. |
| ToR | - | Terms of Reference |
| SoK | - | Survey of Kenya |
| WB | - | World Bank |
| WRMA | - | Water Resources Management Authority |
| WSB | - | Water Services Board |
| WSP | - | Water Service Provider |
| WSS | - | Water Supply and Sanitation |
| WSTF | - | Water Services Trust Fund |
| WWTP | - | Waste Water Treatment Plant |

**Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)**     **FINAL WASTEWATER MASTER PLAN**

**Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region**                        -     **KILIFI TOWN**

# EXECUTIVE SUMMARY

## E1     GOALS AND OBJECTIVES OF THIS STUDY

Goals and objectives are defined in the ToR (Paragraph 7.3) as, "The main goal of the Master Plan is to identify a sound and rational strategy for the development of sewerage services in Mombasa and selected Towns within the Coast Region over the next twenty-five (25) years to improve the quality of effluent to rivers, Indian Ocean, groundwater and to safeguard the health of the city's residents."

The key objective of the proposed Master Plan for Kilifi Town is to come up with a phased investment programme for Immediate / Short Term Plan (2015 – 2020), Medium Term Plan (2021 – 2025), Long Term Plan (2026 – 2040) and recommend a treated effluent disposal / reuse strategy for the effluent in Kilifi Town.

## E2     OBJECTIVES OF THIS REPORT

The Final Wastewater Master Plan Report presents the outputs of the Feasibility Study, the Selected Development Strategy and the Preliminary Design of the planned infrastructure for the Sanitation System of Kilifi Town.

The components of this Report include the following;
- Present Sanitation Situation in the Study Area
- Immediate measures for the improvement of Sanitation Systems
- Future Sewerage System / Coverage Area Expansion
- Analysis of Sewage Generation and Network Analysis
- Formulation of Alternative Wastewater Management Strategies
- Detailed Evaluation of the Preferred Development Strategy including Wastewater Treatment, Social / Environmental Assessment, Economic and Financial Analysis and Multi-Criteria Analysis
- Selection of Wastewater Management Strategies
- Investment and Financial Management Plan
- Proposed Implementation / Development Schedule
- Conclusion of the Master Plan

## E3     STUDY AREA AND DEMOGRAPHY

The Study Area for the Master Plan has been demarcated in consideration of the location of Kilifi Town, projected land use plans for years 2025 and 2040 for Kilifi North sub-County and the nature of development and population densities in the sub-County.

In consideration of the above factors, the study area for Kilifi Waste Water Master Plan lies within the boundary of Kilifi Town which lies within Kilifi North sub-County. The current population of the study area is approximately 41,287.

The sub-locations forming the study area of Kilifi Town and total coverage areas of the study area is given in **Table E1** on **Page E-2**;

**Table E1:  Sub-locations and Study Area**

| Sub-locations | Coverage in the Study Area (km²) | Total Area (km²) |
|---|---|---|
| Takaungu | 1.9 | 15.0 |
| Mnarani | 1.9 | 19.1 |
| Hospital | 11.7 | 13.3 |
| Konjara | 6.5 | 52.4 |
| Kibarani | 1.0 | 16.6 |
| Sokoni | 4.4 | 1.1 |
| Mtondia Majaoni | 14.6 | 43.0 |
| **Total** | **42.0** | **160.5** |

**Figure 2.1** on **Page 2-2** shows the Study Area of Wastewater Master Plan for Kilifi Town**.**
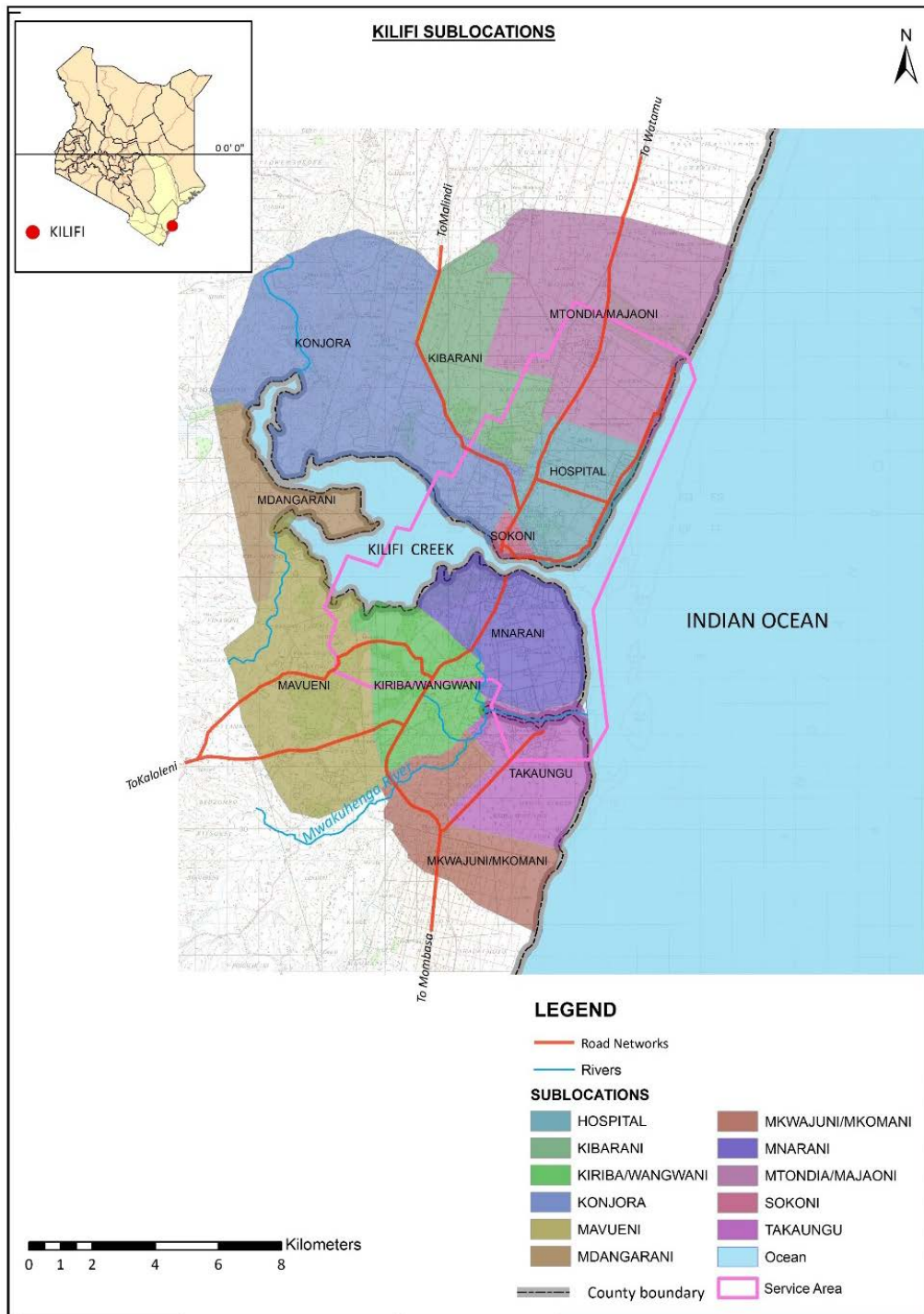


**Figure E1: Study Area of Wastewater Master Plan for Kilifi Town**

From the analysis of previous demographic data obtained from Central Bureau of Statistics (CBS), the average annual growth rate for the Study Area in the intercensal period of 1999 - 2009 is **3.01%.** This is expected to increase because of the planned improvement of infrastructure in Kilifi Town.

Based on a medium growth rate scenario, annual population growth rate taken as increasing from **4.0 – 4.6%**, the population for the Study Area has been projected.

A summary of the projected population of the Study Area is given in **Table E2** below.

**Table E2: Summary of the Projected Population**

| Sub-locations | Projected Population | | | | |
|---|---|---|---|---|---|
| | 2009 Pop. | 2015 | 2020 | 2025 | 2040 |
| Takaungu | 864 | 1,093 | 1,342 | 1,665 | 3,269 |
| Mnarani | 719 | 910 | 1,118 | 1,386 | 2,721 |
| Hospital | 23,663 | 29,941 | 36,779 | 45,615 | 89,553 |
| Konjora | 1,324 | 1,676 | 2,058 | 2,553 | 5,012 |
| Kibarani | 7,079 | 8,957 | 11,002 | 13,645 | 26,789 |
| Sokoni | 2,703 | 3,420 | 4,201 | 5,210 | 10,229 |
| Mtondia Majaoni | 4,936 | 6,246 | 7,673 | 9,516 | 18,682 |
| **Total** | **41,288** | **52,241** | **64,173** | **79,590** | **156,254** |

## E4    WATER DEMAND FORECAST

Water demand forecast for Kilifi Town has been determined based on the regular/ unsuppressed water consumption rates, projected populations, proposed Land-use (Health, Industrial, Commercial, Institutional & Residential Zones) and on the premise that the water distribution network has full coverage of the Study Area.

**Figure E2** below shows the water demand projection for Kilifi Town up to the Ultimate Design Horizon (year 2040).
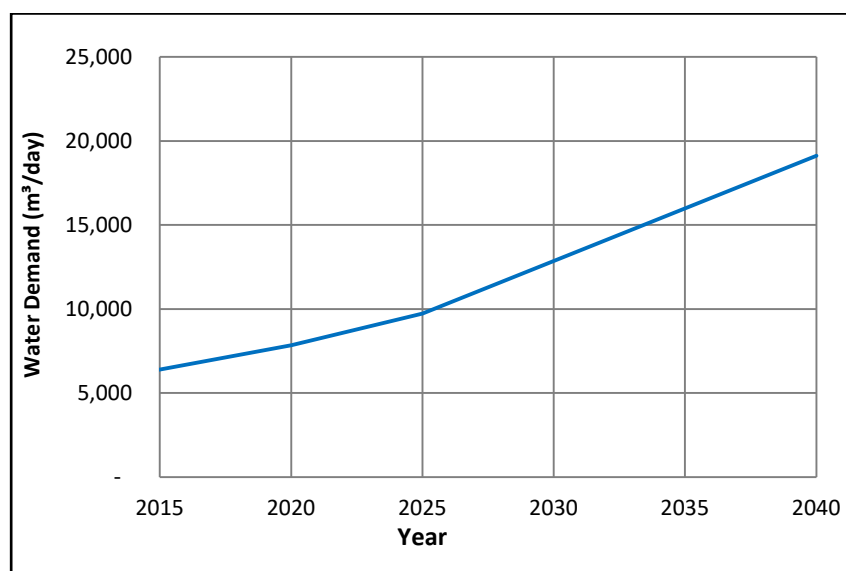


**Figure E2: Water Demand Projection**

## E5    WASTEWATER FLOW PREDICTIONS

The total wastewater generated within a service area is determined by the water consumed (sewage contribution factor of 80%), infiltration into the sewers and splash flows. Assuming a regular water supply condition and full coverage of water distribution system, the projected wastewater flow for Kilifi Town in the year 2040, is approximately **17,000 m³/day**.

However, achieving conditions of regular / unsuppressed water supply and full sewer connections in a Town with Sewerage System is nearly impossible. This is due to limited development of water resources, inadequate water distribution and sewerage networks and prevalent use of on-plot sanitation systems due to topography, affordability, unplanned settlement, etc.

To consider the above situation, the factors of Sewer Connectivity and Water Supply, given in **Table E3** below and **Table E4** on **Page E-4**, have been adopted for the formulation of realistic wastewater generation projection for Kilifi Town.

**Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)**   **FINAL WASTEWATER MASTER PLAN**

**Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region**   -   **KILIFI TOWN**

**Table E3: Sewer Connectivity adopted for Realistic Wastewater Generation Projection**

| Population Category Based on Income Levels | Sewer Connections | |
|---|---|---|
| | 2021 – 2030 | 2031 - 2040 |
| High Income | 20% | 80% |
| Medium Income | 100% | 100% |
| Low Income with Individual Water Connection | 60% | 80% |
| Low Income without Individual Water Connection | 30% | 40% |

**Table E4: Water Supply Status adopted for Realistic Wastewater Generation Projection**

| Population Category Based on Income Levels | Water Supply Status as a % of Regular Water Supply | |
|---|---|---|
| | 2021 – 2030 | 2031 - 2040 |
| High Income | 50% | 80% |
| Medium Income | 50% | 80% |
| Low Income with Individual Water Connection | 50% | 80% |
| Low Income without Individual Water Connection | 50% | 80% |

**Figure E3** below shows the comparative projected wastewater flows for Kilifi Town up to Year 2040 under the Ideal condition (Regular Water Supply, Extensive Water Distribution & Sewerage Networks and 100% Sewer Connections) and Realistic condition (Suppressed Water Supply, Inadequate Water Distribution & Sewerage Networks with gradual improvements and Gradual Sewer Connections);
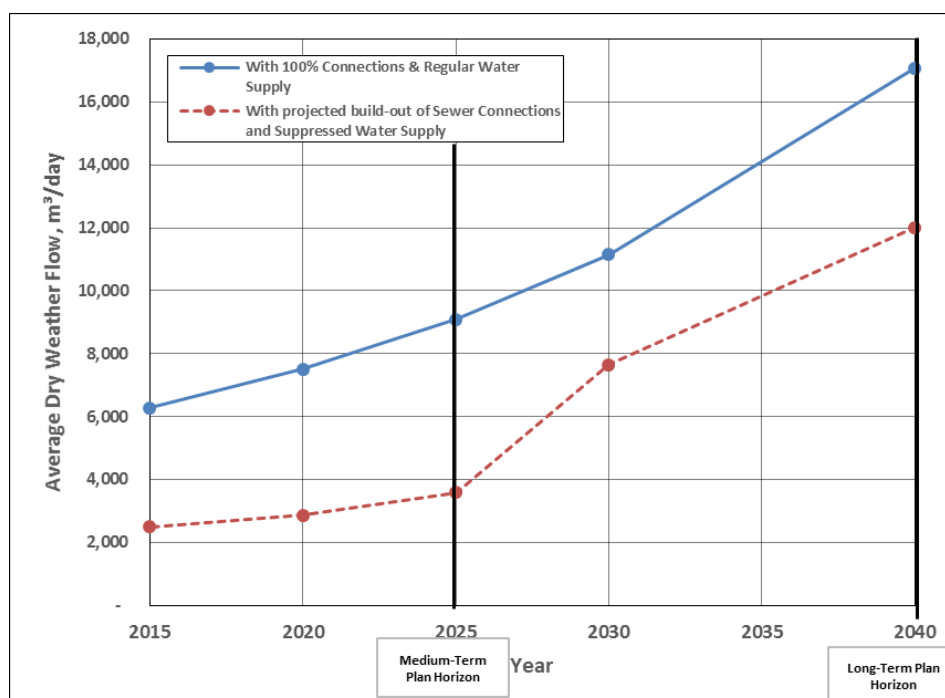


**Figure E3: Comparative Projected Wastewater Flows up to Year 2040**

From **Figure E3** above, the projected wastewater generation based on the realistic conditions of water supply and sewer connections at the Years 2025 and 2040 is 3,800 m³/day and 12,000 m³/day respectively.

**The design of the Sewerage System and Waste Water Treatment Plant has been based on the wastewater flow generation determined based on the realistic conditions of water supply and projected build-out of sewer connections.**

## E6     ALTERNATIVE WASTEWATER MANAGEMENT STRATEGIES

Three alternative Wastewater Management Schemes are feasible for Kilifi Town as briefly described below;

a. Alternative 1: Centralized Scheme with a Wastewater Treatment Plant (WWTP) at Uhuru Farm
b. Alternative 2: Decentralized Scheme with 2 Nr. WWTPs at Uhuru Farm and Baobab
c. Alternative 3: Centralized Scheme with a Long Sea Outfall at Uhuru Farm

The locations of the Wastewater Treatment Plants considered in the above alternative schemes are shown in **Figure E4** below;



**Figure E4: Locations of Alternative Wastewater Treatment Plant Sites**

A summary of the three proposed schemes for Kilifi Town is given in **Table E5** below.

**Table E5: Summary of Alternative Wastewater Management Schemes**

| Alternative Scheme | Conveyance System | | Wastewater Treatment Plants | | | |
|---|---|---|---|---|---|---|
| | Secondary and Trunk Sewers (km) | No. of Pumping Stations | Location | Design Capacity (m³/day) | Treatment Technology | Land Required (Ha) |
| 1 | 78 | 11 | Uhuru Farm | 12,000 | Waste Stabilization Ponds | 30.0 |
| 2 | 76 | 10 | Uhuru Farm (TW1) | 2,000 | | 5.0 |
| | | | Baobab (TW2) | 10,000 | | 24.0 |
| 3 | 78 | 12 | Uhuru Farm | 12,000 | Preliminary Treatment + Sea Outfall | 1.0 |

## E7     MULTI-CRITERIA ANALYSIS AND REVIEW OF DEVELOPMENT STRATEGIES

In the Multi-criteria Analysis, alternative treatment trains and schemes have been evaluated to determine the most suitable wastewater treatment scheme for Kilifi Town.

A summary of the weighted totals for the alternative wastewater treatment trains is given in **Table E6** below.

**Table E6: Weighted Totals for the alternative wastewater treatment trains**

| | Simplicity of Operations & Maintenance | Net Present Value | Environmental Impacts | Land Requirement | Institutional Strength | Weighted Total | Rank |
|---|---|---|---|---|---|---|---|
| *Waste Stabilization Ponds* | 0.486 | 0.548 | 0.456 | 0.052 | 0.410 | 0.457 | 1 |
| *Composite Biofilters* | 0.11 | 0.23 | 0.26 | 0.09 | 0.13 | 0.198 | 3 |
| *Composite Oxidation Ditches* | 0.108 | 0.136 | 0.141 | 0.192 | 0.085 | 0.127 | 4 |
| *Long Sea Outfall* | 0.30 | 0.08 | 0.14 | 0.66 | 0.37 | 0.218 | 2 |

Similarly, a summary of the weighted totals for the alternative schemes developed for Kilifi Town is given in **Table E7** below.

**Table E7: Weighted Totals for the alternative schemes**

| | Simplicity of Operations & Maintenance | Net Present Value | Environmental Impacts | Potential for Reuse | Land Acquisition | Land Use | Weighted Totals | Rank |
|---|---|---|---|---|---|---|---|---|
| *Centralized Scheme with 1Nr WSP System* | 0.175 | 0.153 | 0.301 | 0.050 | 0.227 | 0.094 | 0.526 | 1 |
| *Decentralized Scheme with 2Nr WSP System* | 0.189 | 0.149 | 0.298 | 0.050 | 0.227 | 0.088 | 0.215 | 3 |
| *Centralized Scheme with Long Sea Outfall* | 0.189 | 0.149 | 0.298 | 0.050 | 0.227 | 0.088 | 0.260 | 2 |

From the Multi-criteria Analysis, a Centralized Wastewater Treatment Plant at Uhuru Farm comprising of Waste Stabilization Ponds System is the most suitable Wastewater Management Scheme and is recommended for the Kilifi Sanitation Strategy.

**Table E8** below gives a summary of the details of this recommended Wastewater Management Scheme.

**Table E8: Details of recommended Wastewater Management Scheme – Centralized Scheme**

| Alternative Scheme | Conveyance System | | Wastewater Treatment Plant | | |
|---|---|---|---|---|---|
| | Secondary and Trunk Sewers (km) | No. of Pumping Stations | Location | Treatment Technology | Land Required (Ha) |
| 1 | 78 | 11 | Uhuru Farm | Waste Stabilization Ponds | 30 |

## E8    PROJECT COSTS

The Capital Cost of the selected Wastewater Management Scheme for Kilifi Town has been worked out on the following basis;

a)  Project Implementation planned to be carried out in two phases i.e. Medium-Term Plan (2020 -2025) and Long-Term Plan (2026 - 2040)

b)  The Cost of Civil Works constitute the following fraction of the components total costs;
- Wastewater Treatment Plant – 95%
- Pumping Station – 60%
- Sewers – 100%

Summary of the Capital Costs for the recommended Schemes is given in **Table E9** below;

**Table E9: Capital Costs for the Selected Scheme**

| S/No. | Component | Costs (Kshs) | Costs (USD) [1] |
|---|---|---|---|
| **1** | **Land Acquisition** | **150,000,000** | **1,456,311** |
| **2** | **Civil Works** | **3,111,131,388** | **30,205,159** |
| 2.1 | Wastewater Treatment Plant | 1,174,377,159 | 11,401,720 |
| 2.2 | Pumping Stations | 81,795,510 | 794,131 |
| 2.3 | Sewers | 1,854,958,719 | 18,009,308 |
| **3** | **Electro-Mechanical Works** | **116,339,664** | **1,129,511** |
| 3.1 | Wastewater Treatment Plant | 61,809,324 | 600,091 |
| 3.2 | Pumping Stations | 54,530,340 | 529,421 |
| | **Total Capital Cost** | **3,377,471,052** | **32,790,981** |

A summary of the Phased Investment cost for Kilifi Wastewater Management System is given in **Tables E10** and **E11** below;

**Table E10: Costs for Medium-Term Plan (Year 2020 – 2025)**

| S/No. | Component | Cost (Kshs) | Costs (USD) |
|---|---|---|---|
| 1 | Land Acquisition | 150,000,000 | 1,456,311 |
| 2 | Sewerage System | 917,256,658 | 8,905,404 |
| 3 | Wastewater Treatment Plant | 736,979,575 | 7,155,142 |
| | **Total** | **1,804,236,233** | **17,516,857** |

**Table E11: Costs for Long-Term Plan (Year 2026 – 2040)**

| S/No. | Component | Cost (Kshs) | Costs (USD) |
|---|---|---|---|
| 1 | Sewerage System | 1,074,002,234 | 10427,206 |
| 2 | Wastewater Treatment Plant | 499,232,584 | 4,846,918 |
| | **Total** | **1,573,234,818** | **15,274,124** |

The Operations and Maintenance Costs have been worked out on the following basis;

a)  Electricity Costs at the Pumping Stations has been assumed to increase annually at 4.6% p.a. (same as population) due to increased sewage flow from the increased connections

b)  Annual Maintenance Costs of the Schemes have been calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works

c)  Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule

A summary of the Annual Operations & Maintenance Costs in the first year of operation of the Scheme is given in **Table E12** on **Page E-8**;

**Table E12: Annual Operations & Maintenance Costs (Year 1)**

| S/No. | Component | Costs (Kshs) | Costs (USD) [1] |
|-------|-----------|-------------:|----------------:|
| 1 | Maintenance Costs | 36,928,297 | 358,527 |
| 2 | Electricity Costs | 3,594,089 | 34,894 |
| 3 | Staff Costs | 5,064,000 | 49,165 |
| | **Total O&M Cost** | **45,586,386** | **442,586** |

[1] **– Exchange Rate: 1 USD = 103 Kshs**

## E9   FINANCIAL AND ECONOMIC ANALYSIS OF THE SELECTED DEVELOPMENT STRATEGY

To provide indicators of economic viability and sustainability of the proposed sanitation system, it is important to carry out financial and economic analysis. Financial and economic analysis is used to produce standardised information on Projects, as a basis for making investment decision. The importance of economic analysis in an investment is to help select a Project that contributes to the welfare of a region or a country. On the other hand, financial analysis evaluates Project liquidity and profitability.

The Capital Costs for the Investment Phases and their associated Operations and Maintenance Costs have been used to project the Annual Project Expenditure as summarized in **Table E13** below;

**Table E13: Schedule of Annual Project Expenditures**

| Year | Project Cost, Kshs | O&M, Kshs | Depreciation, Kshs | Total Cost, Kshs |
|------|-------------------:|----------:|-------------------:|-----------------:|
| 2021 | 451,059,058 | - | - | 451,059,058 |
| 2022 | 451,059,058 | - | - | 451,059,058 |
| 2023 | 451,059,058 | 45,586,386.29 | 52,475,626.37 | 549,121,071 |
| 2024 | 451,059,058 | 45,737,338.03 | 69,967,501.83 | 566,763,898 |
| 2025 | - | 45,909,624.29 | 69,967,501.83 | 115,877,126 |
| 2026 | 157,323,482 | 46,081,986.69 | 74,866,918.86 | 278,272,387 |
| 2027 | 157,323,482 | 46,261,933.03 | 80,967,855.54 | 284,553,270 |
| 2028 | 157,323,482 | 46,449,797.02 | 87,068,792.21 | 290,842,071 |
| 2029 | - | 46,645,927.01 | 87,068,792.21 | 133,714,719 |
| 2030 | 235,985,223 | 46,850,686.73 | 96,220,197.23 | 379,056,107 |
| 2031 | 314,646,964 | 47,064,455.87 | 100,134,871.91 | 461,846,292 |
| 2032 | 393,308,705 | 47,287,630.86 | 107,100,014.93 | 547,696,351 |
| 2033 | 157,323,482 | 47,520,625.55 | 104,913,752.94 | 309,757,860 |
| 2034 | - | 47,763,872.00 | 96,626,554.28 | 144,390,426 |
| 2035 | - | 48,017,821.29 | 96,626,554.28 | 144,644,376 |
| 2040 | - | 48,282,944.36 | 94,937,607.75 | 143,220,552 |
| 2045 | - | 48,559,732.84 | 92,047,141.58 | 140,606,874 |
| 2046 | - | 48,848,700.01 | 89,156,675.41 | 138,005,375 |

Assuming adoption of the proposed tariffs and attainment of the projected sewer connections, the projected financial statement has been determined and summarized in **Table E14** on **Page E-9**;

**Table E14**: **Projected Financial Statement of the Project**

| | | | Project Income and expenditure Financial statement (Kshs) | | | | |
|---|---|---|---|---|---|---|
| Year | Total Project Revenue | Billings Not Recovered | Net Project Revenue | Operations & Maintenance | Annual Depreciation | Total Expenditure | Net Revenue |
| 2023 | 108,101,600 | 10,810,160 | 97,291,440 | 45,586,386 | 52,475,626 | 98,062,025 | -770,585 |
| 2024 | 108,101,600 | 10,810,160 | 97,291,440 | 45,737,338 | 69,967,502 | 115,704,853 | -18,413,413 |
| 2025 | 135,360,062 | 13,536,006 | 121,824,056 | 45,909,624 | 69,967,502 | 115,877,140 | 5,946,916 |
| 2026 | 196,004,977 | 19,600,498 | 176,404,480 | 46,081,987 | 74,866,919 | 120,948,919 | 55,455,560 |
| 2027 | 196,004,977 | 19,600,498 | 176,404,480 | 46,261,933 | 80,967,856 | 127,229,803 | 49,174,677 |
| 2028 | 196,004,977 | 19,600,498 | 176,404,480 | 46,449,797 | 87,068,792 | 133,518,604 | 42,885,876 |
| 2029 | 196,004,977 | 19,600,498 | 176,404,480 | 46,645,927 | 87,068,792 | 133,714,734 | 42,689,746 |
| 2030 | 417,021,311 | 41,702,131 | 375,319,180 | 46,850,687 | 96,220,197 | 143,070,899 | 232,248,281 |
| 2031 | 417,021,311 | 41,702,131 | 375,319,180 | 47,064,456 | 100,134,872 | 147,199,343 | 228,119,836 |
| 2032 | 417,021,311 | 41,702,131 | 375,319,180 | 47,287,631 | 107,100,015 | 154,387,662 | 220,931,518 |
| 2033 | 417,021,311 | 41,702,131 | 375,319,180 | 47,520,626 | 104,913,753 | 152,434,395 | 222,884,785 |
| 2034 | 417,021,311 | 41,702,131 | 375,319,180 | 47,763,872 | 96,626,554 | 144,390,443 | 230,928,737 |
| 2035 | 417,021,311 | 41,702,131 | 375,319,180 | 48,017,821 | 96,626,554 | 144,644,393 | 230,674,787 |
| 2036 | 417,021,311 | 41,702,131 | 375,319,180 | 48,282,944 | 94,937,608 | 143,220,570 | 232,098,610 |
| 2037 | 417,021,311 | 41,702,131 | 375,319,180 | 48,559,733 | 92,047,142 | 140,606,893 | 234,712,287 |
| 2038 | 417,021,311 | 41,702,131 | 375,319,180 | 48,848,700 | 89,156,675 | 138,005,394 | 237,313,786 |
| 2039 | 417,021,311 | 41,702,131 | 375,319,180 | 49,150,382 | 89,156,675 | 138,307,076 | 237,012,104 |
| 2040 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 84,820,976 | 134,286,333 | 454,944,902 |
| 2041 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 79,040,044 | 128,505,401 | 460,725,833 |
| 2042 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 71,813,878 | 121,279,236 | 467,951,998 |
| 2043 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,771 | 470,842,464 |
| 2044 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,771 | 470,842,463 |
| 2045 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,772 | 470,842,463 |
| 2046 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,772 | 470,842,462 |

Besides the above revenue collected, the following additional direct/indirect benefits have been considered in the economic analysis:

- Cost savings to customers in terms of health benefits
- Cost savings in terms of safe sewage disposal to the environment

The results of the cost-benefit analysis confirm that the project has favourable BC ratios of between **1.08** to **1.51**. The financial analysis confirms that the project has positive NPVs of **Ksh 1,326,806,064** at 5% cost of capital and **Ksh 435,216,677** at 8% cost of capital and Financial Internal Rates of Return (FIRR) of **11.30** %.

Sensitivity analyses also indicate that the project viability can withstand shocks of 10% but is susceptible to shocks of 20% on net income.

On the other hand, the results of the economic analysis after including other economic benefits showed that the project have a **positive NPV of Kshs 554,613,517** and **EIRR of 16%** at 10% cost of capital.

**It is therefore concluded that the Project is both financially and economically viable.**

**E10     CONCLUSION OF THE MASTER PLAN**

The current sanitation system in Kilifi Town comprising of on-plot sanitation means such as septic tanks and pit latrines and lacking a proper sludge management and disposal facility is a health hazard to the residents and an environmental risk.

As an immediate intervention, construction of Ablution Blocks at designated Public Places and a centralized Sludge Handling Facility is necessary. It is equally important to ensure procurement of Exhaust Vehicles to provide desluging and transport services. A summary of the Immediate Sanitation Measures and their costs estimates are given **Tables E15** and **E16** below.

**Table E15: Details of the Ablution Blocks – Immediate Sanitation Measures**

| Number Proposed | Details of each Ablution Block | | | Total Capital Cost | |
| | No. of Toilets | No. of Shower Rooms | Max. Daily capacity | Ksh. | USD |
|---|---|---|---|---|---|
| 6 | 6 | 2 | 720 | 93,000,039 | 902,913 |

**Table E16: Details of the Sludge Handling Facility – Immediate Sanitation Measures**

| S/No. | Component | Details | Total Capital Cost | |
| | | | Ksh. | USD |
|---|---|---|---|---|
| 1 | Tanker Discharge Bay | • Bar Screens, Collection Chamber, Hard-stand Washing Bay & Parking Space | 58,299,957 | 566,019 |
| 2 | Sludge Drying Beds | • 8 Beds; each 13 x 10m | | |
| 3 | Twin-Septic Tanks | • 2 Tanks; each 98 m³ capacity | | |
| 4 | Land Requirement | • 0.7 Ha | | |
| 5 | Exhaust Discharge Tanker | • Minimum 1 Nr (Either owned by KIMAWASCO or Private Providers) | - | - |

To provide a sustainable sanitation system, a centralized wastewater management system comprising of a gravity sewage conveyance system with limited pumping (11 Nr Pumping Station) and a Waste Stabilization Ponds system based Wastewater Treatment Plant (ultimate capacity – 12,000 m³/d) at Sabaki has been selected from the developed alternative schemes. The implementation of this strategy is to be carried out in 2 phases i.e. Medium Term Plan (2021 -2025) and Long Term Plan (2026 - 2040).

The implementation details of the selected Wastewater Management Scheme in the 2 Phases are given in **Tables E17** below and **Table E18** on **Page E-11**.

**Table E17: Summary of Implementation Cost: Medium-Term Plan Plan (2021 -2025)**

| S/No. | Component | Details | Cost (Kshs) | Cost (USD) |
|---|---|---|---|---|
| 1 | Land Acquisition | • 30 Ha | 1,804,236,233 | 17,516,857 |
| 2 | Sewers | • 225 – 600 mm Dia; Total length 32 km | | |
| 3 | Pumping Stations | • 6 Nr | | |
| 4 | Waste Water Treatment Plant | • Waste Stabilization Ponds; Capacity 6,000 m³/day | | |

**Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)**  **FINAL WASTEWATER MASTER PLAN**

**Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region**  -  **KILIFI TOWN**

**Table E18: Summary of Implementation Cost: Long-Term Plan Plan (2026 -2040)**

| S/No. | Component | Details | Cost (Kshs) | Cost (USD) |
|---|---|---|---|---|
| 1 | Sewers | • 225 – 375 mm Dia; Total length 45 km | | |
| 2 | Pumping Stations | • 5 Nr | 1,573,234,818 | 15,274,124 |
| 3 | Waste Water Treatment Plant | • Waste Stabilization Ponds; Capacity 6,000 m³/d | | |

The financial and economic analysis of the selected scheme confirms both financial and economic viability.

# MAIN REPORT

## 1.0     PROJECT BACKGROUND

The Government of Kenya (GoK) through the Ministry of Water and Irrigation (MWI) has received "credit" from International Development Association (IDA) to undertake the Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region.

Coast Water Services Board (CWSB) is a parastatal (Government Owned and Autonomous) and operates under the Ministry of Water and Irrigation. CWSB covers six Counties which are Mombasa, Kwale, Kilifi, Taita-Taveta, Lamu and Tana River.

The primary outcome of this Study will be to obtain the agreement of all major Stakeholders to a preferred Sewerage Development Strategy most applicable to their needs.

In August 2010, Kenya enacted a new constitution. The Constitution of Kenya 2010 has dramatically altered the administrative structure of the Government from the initial 8 Administrative Provinces to 47 Semi-autonomous Counties.  This autonomy of the Counties vest powers and privileges in each County especially on the provision of essential public services such as Water, Sanitation, Education and other Social Services.

The WaSSIP-AF therefore targets the built-up areas of Towns in six Counties in the Coastal Region as follows:

**Table 1.1:  Project Selected Towns**

| S/No. | County | Urban Centre |
|-------|--------|--------------|
| 1. | Mombasa County | Mombasa including Island, West Mainland, South Mainland / Likoni and North Mainland |
| 2. | Kwale | Kwale, Ukunda / Diani and Part of Mariakani. |
| 3. | Kilifi | Malindi, Kilifi, Watamu, Mtwapa and Part of Mariakani |
| 4. | Taita Taveta | Voi and Taveta |
| 5. | Lamu | Lamu Island |
| 6 | Tana River | Hola |

The Terms of Reference (ToR) included seven Towns but in the course of the study five upcoming Towns (Mariakani, Taveta, Ukunda/Diani and Watamu) were added as an addendum.

It is therefore required that the formulated Program shall be aligned to respect and respond to the requirements of the new Constitution. A key benchmark of the new Constitution is stipulated under Chapter IV-BILL OF RIGHTS, paragraph 45(1) (b) and (d) which stipulates: *"Every person has the right to (b)............reasonable standards of sanitation and (d) clean and safe water in adequate quantities."*

A Location Plan for the twelve Project Towns is given in
**Figure 1.1 on Page 1-2.**

**Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)**     **FINAL WASTEWATER MASTER PLAN**

**Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region**                                              -     **KILIFI TOWN**
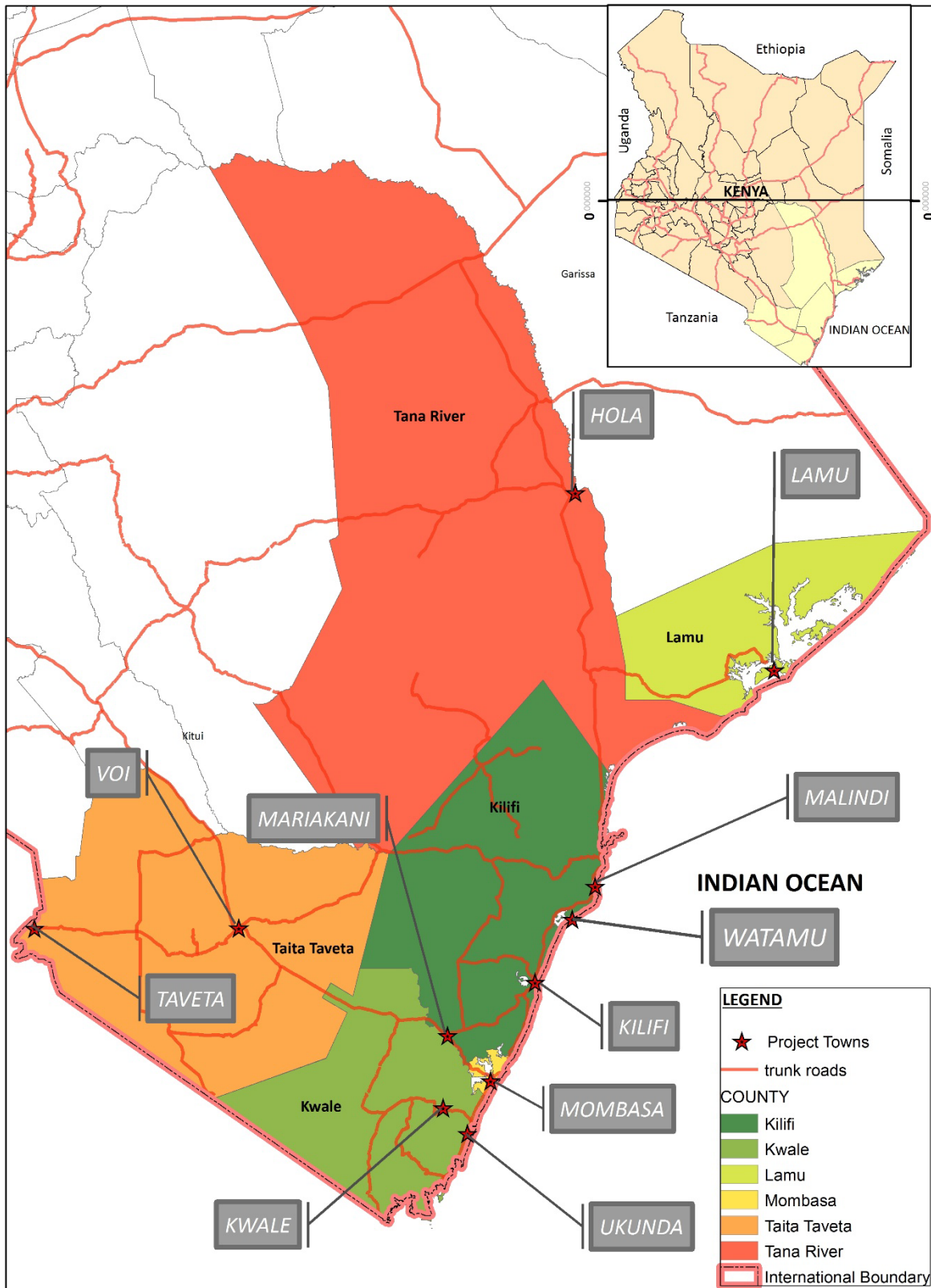
**Figure 1.1: Location Plan for the Project Towns**

## 1.1    Goals and Objectives of this Study

Goals and objectives are defined in the ToR (Paragraph 7.3) as, "The main goal of the Master Plan is to identify a sound and rational strategy for the development of sewerage services in Mombasa and selected Towns within the Coast Region over the next twenty-five (25) years to improve the quality of effluent to rivers, Indian Ocean, groundwater and to safeguard the health of the residents."

The key objective of the proposed Master Plan for Kilifi Town is to come up with a phased investment programme for Immediate / Short Term Plan (2015 - 2020), Medium Term Plan (2021 - 2025), Long Term Plan (2026 - 2040) and recommend a treated effluent disposal / reuse strategy for the effluent in Kilifi Town."

## 1.2    Execution of the Study

To meet the goals and objectives of the Study, the following reports have been submitted:

- D1 – Inception Report
- D2 – Report on Condition Survey and Environmental Audit of the Existing Facilities,
- D3 – Immediate Urgent Works Report / Final Design Report
- D4 – Detailed Designs and Tender Documents for Immediate Urgent Works
- D5A – Technical Note 1 - Socio Economic Conditions, Mapping & Land Use
- D5B – Technical Note 2 - Waste Water Flow Predictions & Formulation of Sewerage Development Strategies
- D7 – Preliminary Design Report for Medium Term Works including Phased Investment Schedule for Sewers and Waste Water Treatment Plants
- D8 – Preliminary Environmental and Social Impact Assessment (ESIA) & Preliminary Resettlement Action Plan (RAP) for the Preferred Development Strategy

The Final Wastewater Master Plan Report presents the outputs of the Feasibility Study, the selected Development Strategy and the Preliminary Design of the planned infrastructure for the Sanitation System of Kilifi Town.

- D9 – Final Master Plan Report

## 1.3    Objectives of this Report

The Tasks to be addressed in the Final Wastewater Master Plan Report include the following:

- Present Sanitation Situation in the Study Area
- Immediate measures for the improvement of Sanitation Systems
- Future Sewerage System / Coverage Area Expansion
- Analysis of Sewage Generation and Network Analysis
- Formulation of Alternative Wastewater Management Strategies
- Detailed Evaluation of the Preferred Development Strategy including Wastewater Treatment, Social / Environmental Assessment, Economic and Financial Analysis and Multi-Criteria Analysis
- Selection of Wastewater Management Strategies
- Resolution of Issues raised by the detailed Evaluation including Preliminary Risk Management Plan
- Investment and Financial Management Plan
- Proposed Implementation / Development Schedule
- Conclusion of the Master Plan

## 2.0    PROJECT AREA DESCRIPTION

### 2.1    Location and Administration

Kilifi Town is a resort Town located in the South Eastern part of Kenya along the Indian Ocean Coast and astride the Kilifi Creek. It is 35 km northeast of Mombasa and lies between Latitude $3^0$20'S and $4^0$00'S and Longitude $39^0$05'E and $40^0$14'E.

Kilifi Town is the headquarters of Kilifi County. Kilifi County has seven administrative sub-counties namely; Kilifi south, Kilifi North, Ganze, Malindi, Magarini, Kaloleni and Rabai. Kilifi Town lies within Kilifi North sub-County. Kilifi County borders Kwale County to the south west, Taita Taveta County to the west, Tana River County to the north, Mombasa County to the south and Indian Ocean to the east.

The water supply and sanitation systems in Kilifi Town is managed by Kilifi - Mariakani Water and Sewerage Company Ltd (KIMAWASCO).

### 2.2    Study Area

The Study Area for the Master Plan has been demarcated in consideration of the location of Kilifi Town, projected land use plans for years 2025 and 2040 for Kilifi North sub-County, nature of development and population densities in the sub-County.

In deliberation of the above factors, the study area for Kilifi Waste Water Master Plan was selected within the boundary of Kilifi Town. The Study Area lies within 7 sub-locations of Kilifi North sub-County covering approximately 26% of the sub-County in the Study Area. The current population of the study area is approximately 53,000 persons.

The sub-locations forming the study area of Kilifi Town indicating coverage areas of the study area and total sub-County area given in **Table 2.1** below;

**Table 2.1:  Sub-locations and Study Area**

| Sub-locations | Total Area (km²) | Coverage in the Study Area (km²) |
|---|---|---|
| Takaungu | 15.0 | 1.9 |
| Mnarani | 19.1 | 1.9 |
| Hospital | 13.3 | 11.7 |
| Konjara | 52.4 | 6.5 |
| Kibarani | 16.6 | 1.0 |
| Sokoni | 1.1 | 4.4 |
| Mtondia Majaoni | 43.0 | 14.6 |
| **Total** | **160.5** | **42.0** |

**Figure 2.1** on **Page 2-2** shows the Study Area of Wastewater Master Plan for Kilifi Town.

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)  
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT  
- KILIFI TOWN
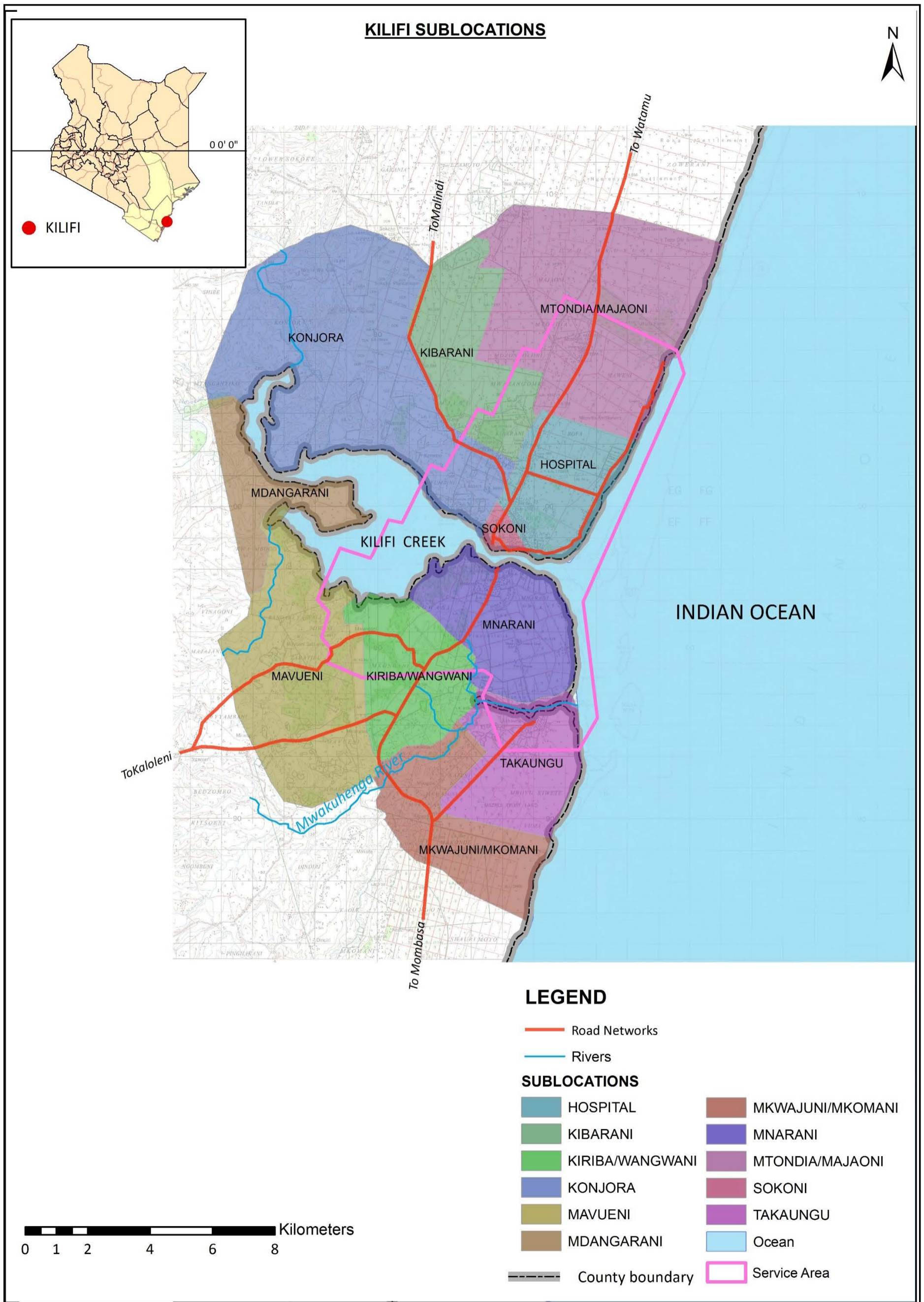
**Figure 2.1: Study Area of Wastewater Masterplan for Kilifi Town**

## 2.3     Climate

Kilifi County has a bimodal rainfall pattern. Long rains fall from April to June, with a peak in May and the short rains fall from October to December. The average annual rainfall ranges from 400mm in the hinterland to 1,200 mm at the coastal belt. Kilifi North Sub-County forms the southern part of the Athi catchment area draining to the Indian Ocean.

Kilifi Town is generally hot and humid throughout the year with average day temperatures of 24°C. The lowest temperature is experienced during the long rainy seasons. The average relative humidity along the coastal belt is 65% but with a decrease towards the hinterland.

## 2.4     Topography, Geology and Soils

Kilifi has four major topographical features with marked geological and rainfall characteristics which dictate the resource potential and land use patterns. These are the Coastal Plain, the Foot Plateau, the Coastal Range and the Nyika Plateau.

The Coastal Plain is a narrow belt, varying in width between 3 km and 20 km. It lies below 30 m above sea level, except for occasional prominent peaks on the Western boundary, which includes major hills like Mwembetungu and Mamburi sand dunes. The rest of the area is broken by creeks and estuaries, giving rise to excellent marine and estuarine swamps, with mangrove forests and untapped potential for marine culture. The zone is composed of Triassic sediments of marine and deltaic origin, and includes coral limestone, marble, clay stones and other alluvial deposits, yielding deep soils which support agriculture. Kilifi Town lies within the Coastal Plains of Kilifi County.

The Foot Plateau lies to the west of the Coastal Plain, with slightly undulating terrain between 60m and 135m altitudes. The plateau is characterised by a seaward-sloping pine plain, where the surface is covered in dry water courses with underlying Jurassic sediments consisting of shell sandstone and impervious clays. It supports grassland and stunted vegetation with a high risk of soil erosion.

The Coastal Range Zone has a distinct low range of sandstone hills of about 150 m to 420 m high. These hills (peaks) include Daka, Wacha, and Gaabo in the North-West, Simba, Kiwara, and Jibana in Kilifi area; and Mazeras and Mwangea in Kaloleni. This zone has good rainfall and fertile soils, containing some of the best farming areas in the County. This hinterland forms the rangelands of Coast region.

The Nyika Plateau occupies the lower-lying ground along the western side of the County. It accounts for about 60% of the total County area. It has gently undulating terrain, which drops from 300m to 180m above sea level. It is overlain by sandstone and poor soils. The zone ranges from semiarid to arid, with little basis for rain-fed crop farming. It is mainly suited for livestock development and pineapple or horticultural crop production (in some areas).

The geology of Kilifi Town consists of sediments and sedimentary rocks of several types; the Jurassic systems, the tertiary system and the quaternary system and each of these units has several formations. The sedimentary rock systems runs parallel to the coastline in a north east - south west direction. The sediments found in Kilifi were deposited at various stages of geological history.

For preliminary assessment of the soil conditions in Kilifi Town, *Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980* has been used. In general, most of the soil formations along the coast are of coral parents. The soils within Kilifi Town are typically a mixture of well drained, deep, dark red to reddish brown, friable, sandy clay loam to sandy clay, with top soil of loamy sand and well drained, very deep, yellowish red, very friable, fine sandy loam to fine sandy clay loam.

## 2.5    Economic Activities

Tourism is a major economic activity with beach hotels and water sports. Kilifi Town houses ancient monuments - the ruins of 14$^{th}$ century slave trading settlement and a reptile rescue park located at the southern end of Kilifi North.

Kilifi County has high potential for agricultural production since its characterized by fertile soils and a favorable climatic condition suitable for dairy and crop farming. The bulk of the arable land is either under-utilized or still lies unutilised. Most of the farming that takes place is shifting cultivation of food crops including maize, cassava, cowpeas, beans and green grams inter-planted with permanent tree crops of cashew nuts, coconuts, mangoes, bananas, paw-paws and citrus fruits.

In the rangelands, the farmers practice mixed farming with greater reliance on small stock. There exist extensive grazing lands under traditional pastoralism. Mixed herds of goats, sheep and cattle are predominant and exceed the carrying capacity in these areas. Extensive grazing leads to destruction of the vegetation and hence erosion. There is a dire need to intensify the growth of fodder crops and to educate farmers on  proper use of grazing lands.

The current farming systems, have to be intensified to sustain the future levels of consumption per capita. With modern farming methods, agriculture has potential to be a leading economic activity.

## 2.6    Existing Water Supply and Sanitation Systems

### 2.6.1    Water Supply

The main source of water supply for Kilifi Town is Baricho Wells located approximately 145km away at Sabaki River. Before transmission to Kilifi Town, the abstracted water is chlorinated at Baricho and Break Pressure Tanks at Sokoke and Mavueni.

Details  of the existing Water Supply System are summarised in **Table 2.2** below:

**Table 2.2: Summary of Existing Water Supply System in Kilifi Town**

| | |
|---|---|
| Water Sources | Baricho wells at Sabaki River |
| Water Treatment | Chlorination at Baricho and at Break Pressure Tanks located at Sokoke and Mavueni |
| Water Pumps | At Baricho wells |
| Water Mains | Gravity Transmission Mains DN 300mm -150mm AC, GI and uPVC pipes |
| Water Storage | 2Nr.  250 m$^3$ at Boma<br>1 Nr. 500m$^3$ at Kilifi Town<br>2Nr. 150m$^3$ at Mavueni<br>2Nr. 50m$^3$ each reservoir at Sokoke |
| Water Distribution | 180km of AC, GI, uPVC pipes, diameter varying in sizes from 50 to 300mm length approximate length 95km of tertiary mains |

The Water Supply for Kilifi is generally insufficient and requires extension of the Distribution Network to adequately serve the urban and peri-urban areas and cater for the future needs of the growing population. Preparation of a Water Distribution Master Plan is in progress to address these challenges.

Also upon implementation of Mwache Dam for Mombasa and Kwale Counties which is currently at design review stage, the bulk supply from Baricho Wells will be dedicated to Malindi and Kilifi Towns and its environs and will greatly reduce the water deficit.

### 2.6.2    Sanitation System

At present, Kilifi Town has no sewerage system. The use of on-plot sanitation systems such as pit latrines and septic tanks for disposal of effluent is prevalent. The major problem faced is the lack of a proper sludge management system such as a Sludge Handling Facility for the discharge of septage by the exhaust vacuum tankers. Thus, septage from septic tanks is discharged directly to the environment.

In situations of suppressed water supply, such as in Kilifi Town, the use of on-plot sanitation systems though unsustainable environmentally is manageable. If the water supply situation is improved through the development of additional water resources and expansion of water distribution networks, as planned for Kilifi Town, the use of on-plot sanitation systems will not suffice and thus health and environmental hazards are bound to occur.

In summary, the current sanitation infrastructure in Kilifi Town is insufficient to meet the sanitation needs of the growing population and there is need for a development of a water-borne sanitation system which is environmentally sustainable.

### 2.7    Immediate Measures for the Improvement of Sanitation Systems

The Final Wastewater Master Plan for Kilifi Town describes the development strategy for the long-term water-borne sanitation system comprising of a wastewater collection / conveyance system and the treatment / proper disposal of the treated effluents. However, the long-term sanitation strategy is not planned for immediate implementation.

In consideration of the current sanitation systems and the growing sanitation needs, an immediate intervention is urgently required. Thus, Immediate Sanitation Measures have been developed. These measures include construction of Ablution Blocks in public places and Sludge Handling Facilities as described in the following sub-sections.

### 2.7.1    Ablution Blocks

Ablution Blocks are essential in Kilifi Town for improved access to sanitation facilities especially in public places e.g., markets, bus stops, schools, etc. They are important to market vendors, market customers, long distance travelers, bus operators and the general public. Their locations in Kilifi Town will be selected in consultation with the CWSB and the Kilifi County Government.

Considering the population densities and the number of public utilities, a total of six (6) Ablution Blocks is proposed for construction in Kilifi Town. Each Ablution Block comprises of six (6) toilets and two (2) Shower Rooms with equal number for each gender i.e. Ladies and Gents. The allocated number of toilets in each Ablution Block ensures provision of sufficient service levels for the target population. It is estimated that on average, a user spends 5 minutes in the facility. Thus, for a single facility with 6 toilets and 10 hours of operation in a day, a maximum number of 720 persons can be served in a day.

Each section (ladies and gents) is provided with a toilet fitted with special amenities for use by disabled persons. The "Gents" are provided with separate urinals to increase the service levels especially during the peak hours.

The shower rooms are equipped with a dressing area and hand-wash basins. In addition, a spacious common area with hand-wash basins, hand driers and wall mounted mirrors is provided.

Each of the units is fitted with coat hangers behind the doors for convenience. To enhance natural lighting within the facility, transparent polycarbonate roofing material have been incorporated in the design. Proper ventilation is ensured by the louvered windows and gap

between the ring beam and the roof. The gap is fitted with louvre blocks and plastic coated coffee tray wires to prevent insect entry.

A septic tank with a holding capacity of 16 m$^3$ is provided at the facility for storage and partial treatment of sewage. The septic tank will require desludging after every 3 months with septage disposal at the proposed Sludge Handling Facility, to be implemented as part of the immediate sanitation intervention. In addition, a 5,000-litre water tank mounted on a 3.5m high reinforced concrete tower within the facility provides a 3-day storage of potable water.

Other services provided at the site include; electricity for use at night and for security lighting, boundary chainlink fence where applicable including a 4m wide metallic gate.

Permission to use the facility is to be on a pay-per-use basis. This is an effective model used in many parts of the country to raise money required for operation and maintenance. A personnel office complete with a storage room including a shop for essential basic commodities shall be provided at the entrance of the facility with grilled opening for ease of payment before use.

A typical Site Layout, Plan and Elevations of the proposed Ablution Block are given in **Figures 2.2 and 2.3** on **Pages 2-6** and **2-7 respectively.**
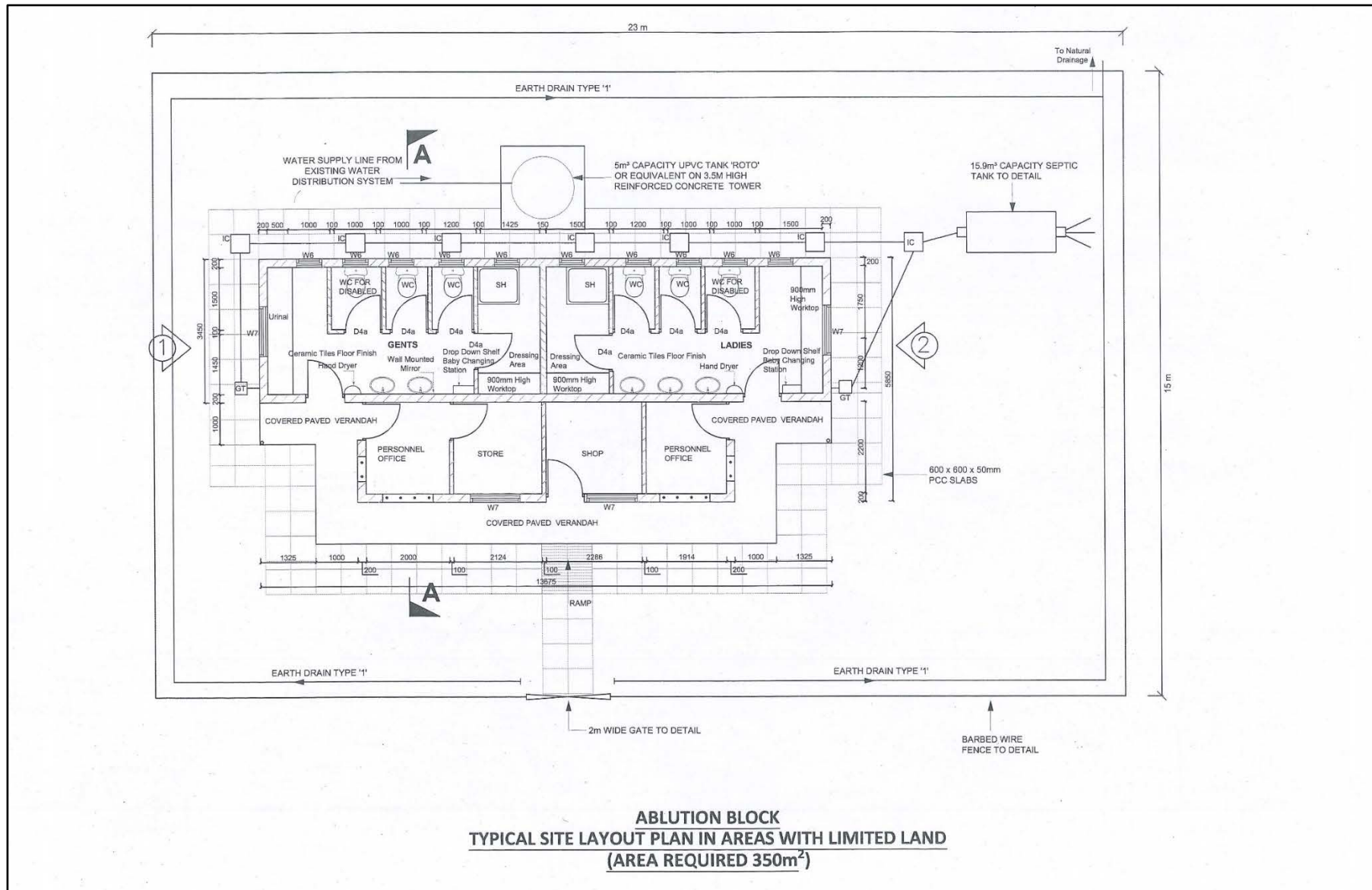
**Figure 2.2:  Typical Site Layout Plan for an Ablution Block**
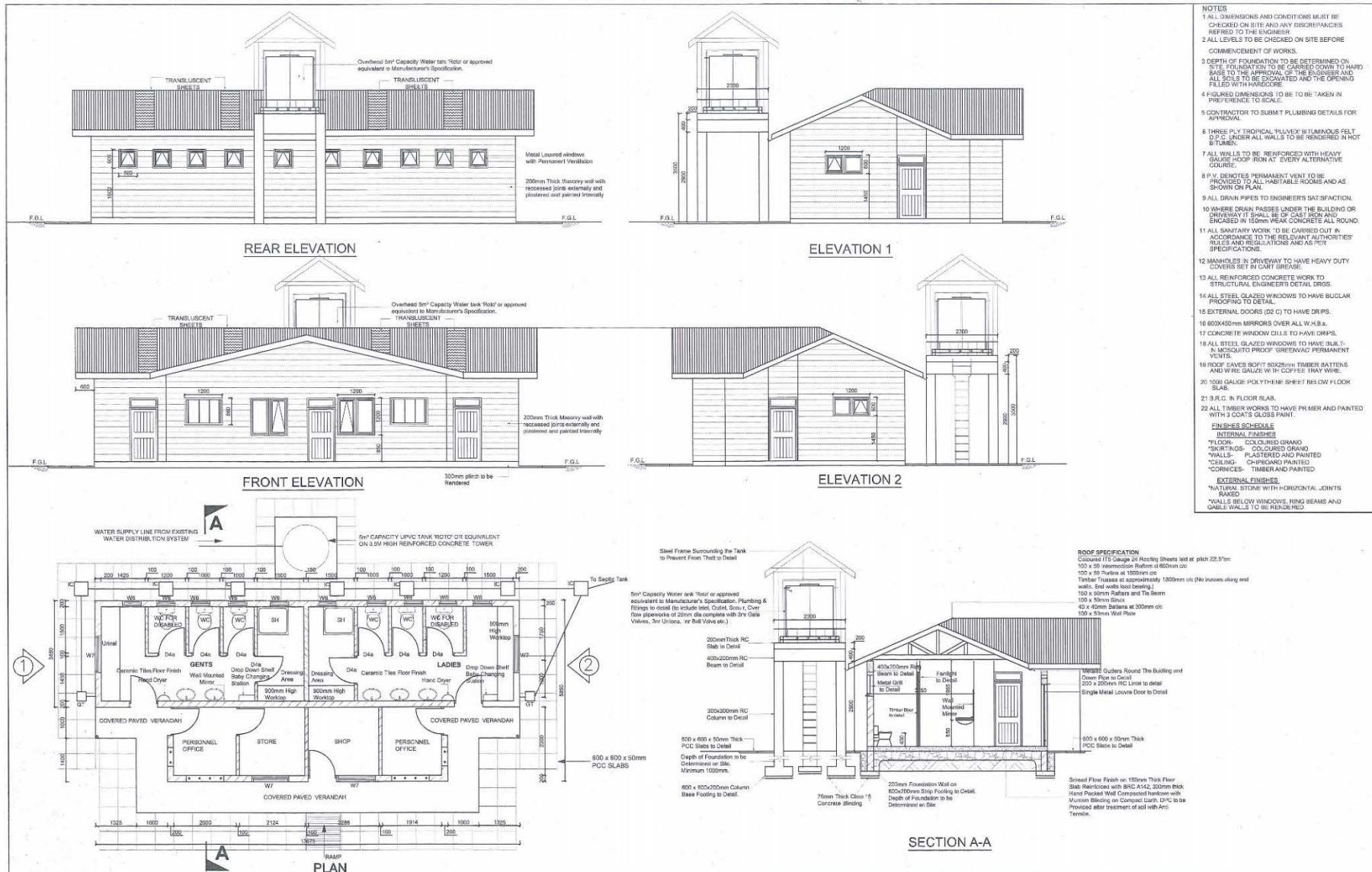
**Figure 2.3: Typical Plan, Views and Sections of an Ablution Block**

## 2.7.2    Sludge Handling Facility

A Sludge Handling Facility is a small-scale treatment plant for the treatment and safe disposal of septage from on-plot sanitation systems such as septic tanks or pit latrines. Septage from the on-plot sanitation systems is conveyed to the facility via an Exhaust Vacuum Tanker.

With exception of the Screens, Sludge Handling Facility relies on biological processes for the treatment of septage. This results to low capital investment requirement as well as Operations and Maintenance requirements (skills, complexity and labour costs), thus making it a suitable Immediate Sanitation Measure.

An ideal location for a Sludge Handling Facility is a site within economical distance to the service area but outside the residential developments and environmentally sensitive areas. At present, the Water Service Provider (KIMAWASCO) has indicated availability of land for construction of this facility near Kilifi Town. This location has been evaluated and found to be suitable.

The proposed Sludge Handling Facility will comprise of the following units;

a.    Exhaust Vacuum Tanker Discharge Bay
b.    Sludge Drying Lagoons
c.    Septic Tanks complete with Soak Pits and French Drains
d.    Associated Site and Ancillary Works, including Operator's Office/ Guard House

Constructed wetlands are the alternative treatment unit to Septic Tanks for polishing of filtrate from Sludge Drying Beds/Lagoons. However, they require large footprint than the Septic Tanks and thus not suitable for urban areas like Kilifi Town where land is limited and the cost of land considerably high.

A Schematic Layout Plan showing the arrangement of the units for the Proposed Sludge Handling Facility is given in **Figure 2.4** on **Page 2-10.**
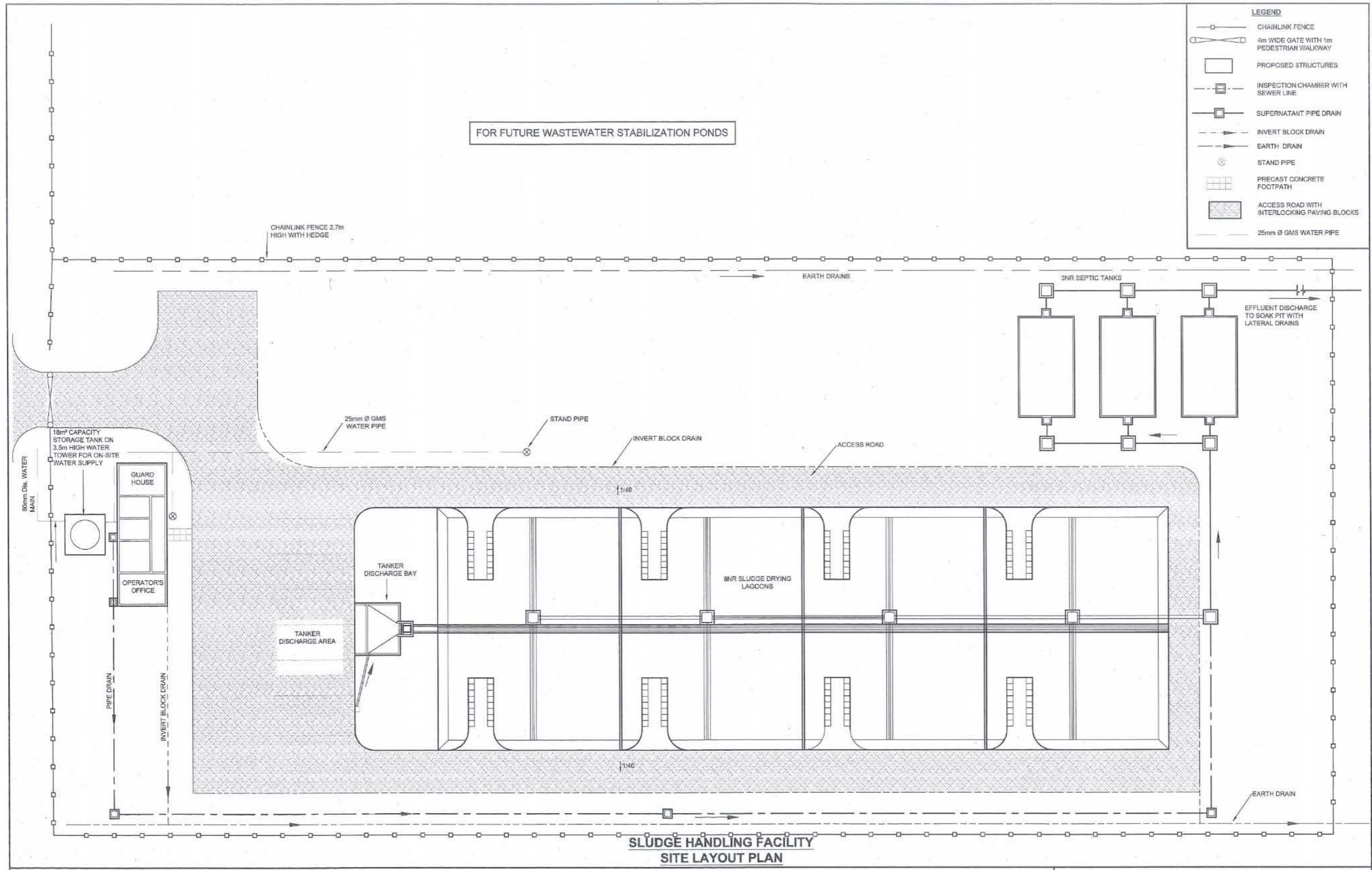
**Figure 2.4:  Schematic Layout Plan of the proposed Sludge Handling Facilities**

A brief description of the constituent treatment units in the proposed Sludge Handling Facility is given in the following sub-sections;

### 2.7.2.1 Exhaust Vacuum Tanker Discharge Bay

The Discharge Bay comprises of a septage discharge area which serves as the Inlet Works for the Sludge Handling Facility. An Exhaust Vacuum Tanker discharges septage at the Discharge Bay through Bar Screens into a Collection Chamber. The Discharge Bay is also provided with Hard-stand Washing Bay and Parking Space.

The discharged septage and wash water from the Washing Bay are pooled into the Collection Chamber and conveyed to the Sludge Drying Bed / Lagoons via an Open Channel to be provided with precast concrete cover slabs and guardrails for safety.

The Discharge Bay requires regularly cleaning for odour, flies and other disease-vectors control especially after each exhauster discharge session. A stand pipe will be provided to facilitate washing and flushing of septage once discharged.

### 2.7.2.2 Sludge Drying Lagoons / Beds

Septage is mostly liquid with small amounts of solids. Treatment of septage entails reducing sludge weight and volume with the aim of lowering the disposal costs of the residual sludge and reducing the potential health risks associated with septage.

Sludge Drying Lagoons are open areas on which the septage is spread for dewatering and air-drying. It comprises of filter media, perforated pipes at the beds and a Collection System. The filtrate from septage once directed into the Collection System is conveyed to Septic Tanks for further treatment and pathogen reduction.

The Sludge Drying Lagoons are made up of the following parts:
- Concrete Beds and Walls
- Sand and Gravel as Filter Media
- Splash Slab
- Under-drainage System
- Access Structures

A Sludge Drying Lagoon has intrinsic process reliability and flexibility. However, during wet season, the efficacy is hindered and longer drying periods are required.

For efficient operation of Sludge Drying Lagoons the following measures need to be undertaken;
a) Periodic unblocking of Collection System through the rodding chambers
b) Periodic monitoring and replacement of Filter Media when necessary
c) Maximum permissible sludge accumulation level to be observed for optimum operation
d) Proper drying of sludge once a bed is filled up
e) Careful removal of dried up sludge without scooping of filter media
f) Safe disposal of dried sludge to a landfill, agricultural use etc.

### 2.7.2.3 Septic Tank

A septic tank refers to a water-tight, covered, sub-surface receptacle for wastewater treatment. At the Sludge Handling Facility, Septic Tanks will be adopted for polishing of the filtrate from Sludge Drying Beds before discharge into the environment through soak pits French Drains.

Septic Tanks achieve polishing of septage filtrate by carrying out the following processes:
a) Separation of settleable and floating solids from the liquid
b) Digestion of organic matter by anaerobic bacterial action
c) Storage of digested solids during detention period
d) Allowing clarified liquids to discharge for final disposal

Septic tanks require periodic desludging after accumulation of solid sludge and disposal of residual sludge through burying or conversion into fertilizers.

### 2.7.2.4 Associated Site and Ancillary works

To enhance access, proper drainage and security, the following site and ancillary works have been proposed at the Sludge Handling Facility;

    i. Chain-link Fence and 4m wide Gate
    ii. Access Roads paved with interlocking concrete blocks
    iii. Operator's Office, Store, Washroom and Guard House
    iv. Site drainage system
    v. Onsite water supply

### 2.7.2.5 Design Criteria for Sludge Handling Facility

A summary of the Design Criteria adopted in the sizing of the proposed Sludge Handling Facility for Kilifi Town is given in **Table 2.3** below.

**Table 2.3: Design Criteria - Sludge Handling Facility**

| Treatment Unit | Design Parameter | Value |
|---|---|---|
| Sludge Drying Bed | • Sludge accumulation rate | 0.025 $m^3$/ca/yr |
| | • Sludge drying period | 3 Months |
| | • Depth of media | 300 mm |
| | • Sludge accumulation depth | 150 mm |
| Septic Tank | • Aggregated sewage generation factor | 0.25* |
| | • Retention period | 1 day |
| | • Sludge accumulation | 0.04 $m^3$/capita/year |

*\*Aggregated sewage generation factor of 25% is based on the distributive use of Septic Tanks and Pit Latrines by the respective Income Levels of the Population and sludge reduction in the On-Plot Sanitation Systems due to the anaerobic digestion during the period of storage*.

### 2.7.2.6 Components of the Proposed Sludge Handling Facility

Considering that the Immediate Sanitation Measures for Kilifi Town are intended to serve the population up to the Year 2020, the Facility has been designed to cater for approximately 25% of the projected current population i.e. **10,000 persons**. This is because the embracing of the Sludge Handling Facilities is expected to be gradual. Rigorous Public Health Campaigns are necessary for full usage to be experienced.

Details of the various components of the proposed Sludge Handling Facility in Kilifi are summarised in **Table 2.4** below

**Table 2.4: Components of the Proposed Sludge Handling Facility**

| S/No. | Treatment Unit | Details |
|---|---|---|
| 1. | Discharge Bay | • Bar Screens & Collection Chamber<br>• Hard-stand Washing Bay & Parking |
| 2. | Sludge Drying Lagoons / Beds | • 8 No. Beds; each 13 x 10 m<br>• Sludge drying period: 3 months<br>• Treatment zone media = 500 mm thick |
| 3. | Septic Tanks | • 3Nr Twin-Tank; each 9.6 x 5.4 x 1.9 m (L x W x H)<br>• Desludging Interval = 0.2 years |

Approximately **0.5Ha** of land is required for the construction of the proposed Sludge Handling Facility to serve the immediate sanitation needs of Kilifi Town**.**

Co-location of Sludge Handling Facility and Wastewater Treatment Plant is recommended for efficient land use and for shared use of common units and facilities; thus, Uhuru Farm area is ideal.

### 2.7.3    Implementation Cost for Immediate Measures

Engineer's Cost Estimate has been determined for the Immediate Measures for Improvement of Sanitation Systems in Kilifi Town based on the unit costs from recent contracts of similar scope and nature. Detailed Unit Costs are discussed in **Chapter 8** of this Report.

A summary of the Implementation Costs is given in **Table 2.5** below.

**Table 2.5: Implementation Costs for Immediate Measures**

| S/No. | Component | Number to be Provided | Cost, Ksh. | Cost, USD |
|-------|-----------|-----------------------|------------|-----------|
| 1. | Ablution Blocks | 6 | 93,000,039 | 902,913 |
| 2. | Sludge Handling Facility | 1 | 58,299,957 | 566,019 |

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

## 3.0    DEMOGRAPHY, LAND USE AND URBAN DEVELOPMENT

### 3.1    Demography and Population Dynamics for Kilifi Town

Demographic data from Central Bureau of Statistics (CBS), for the intercensal periods between 1979 to 2009 have been analysed to establish trends in terms of population size and intercensal growth rates, to develop future population projection patterns in Kilifi Town.

#### 3.1.1    Previous Population Trend

From the analysis of the previous Kenya Population and Housing Census data, it is construed that between intercensal periods, existing sub-locations are split to form new sub-locations and the areas covered by the sub-locations, in such cases, vary between the intercensal period.

A summary of previous inter-censal population data for Kilifi North Sub-County is given in **Table 3.1** below.

**Table 3.1: Inter-censal Population Data (1979 - 2009) for Kilifi North Sub-County**

| Sub-locations | (Census Period) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1979 | | | 1989 | | | 1999 | | | 2009 | | |
| | Pop. | Area (km²) | Pop. Density (person/km²) | Pop. | Area (km²) | Pop. Density (person/km²) | Pop. | Area (km²) | Pop. Density (person/km²) | Pop. | Area (km²) | Pop. Density (person/km²) |
| Takaungu | 3,901 | 15.0 | 260.07 | 6,836 | 38 | 179.89 | 5,457 | 15.8 | 345.38 | 6,656 | 15.0 | 443.73 |
| Mnarani | 656 | 15.0 | 43.73 | | | | 5,981 | 19.1 | 313.14 | 7,392 | 19.1 | 387.02 |
| Hospital | | | | 5,118 | 23 | 222.52 | 15,236 | 11.9 | 1,280.34 | 27,017 | 13.3 | 2,031.35 |
| Konjara | 856 | 13.0 | 65.85 | 9,254 | 78 | 118.64 | 8,486 | 47.0 | 180.55 | 10,695 | 52.4 | 204.10 |
| Kibarani | 2,860 | 38.0 | 75.26 | | | | 8,363 | 16.8 | 497.80 | 10,163 | 16.6 | 612.23 |
| Sokoni | | | | | | | 6,709 | 1.1 | 6,099.09 | 8,010 | 1.1 | 7,281.82 |
| Mtondia Majaoni | 7,942 | 53.0 | 149.85 | 9,657 | 40 | 241.43 | 9,439 | 40.8 | 231.35 | 14,533 | 43.0 | 337.98 |
| Total | 16,215 | 134 | 121.01 | 30,865 | 179 | 172.43 | 59,671 | 153 | 391.29 | 84,466 | 161 | 526.27 |

Population data is dependent on the coverage considered; for the same Town and time, a larger area would give a higher population. The use of population figures to establish inter-censal population growth rate in a sub-location with varying coverage areas between intercensal period is inaccurate due to the variability of coverage area. It is therefore prudent to adopt the use of population density as a measure of demographic trend where sub-location coverage varies between intercensal period, as is the case in Kilifi Town.

The intercensal Annual Population growth rates based on the population densities for the sub-locations within the study area of Kilifi North Sub-County are given in **Table 3.2** below.

**Table 3.2: Previous Intercensal Annual Population Growth Rates**

| Sub-locations | Intercensal Period | | |
|---|---|---|---|
| | 1979 - 1989 | 1989 - 1999 | 1999 - 2009 |
| Takaungu | 1.70% | 6.20% | 2.54% |
| Mnarani | | 6.20% | 2.14% |
| Hospital | - | 19.12% | 4.72% |
| Konjara | 5.00% | 8.30% | 1.23% |
| Kibarani | | 8.30% | 2.09% |
| Sokoni | - | - | 1.79% |
| Mtondia Majaoni | 4.89% | - 0.43% | 3.86% |
| **Total** | **3.60%** | **8.54%** | **3.01%** |

From **Table 3.2** on **Page 3-1**, the average annual population growth rate for Kilifi North Sub-County in the last intercensal period (1999 to 2009) is **3.01%.** This is comparable to the average national growth rate of 3.19% for the period 1999 to 2009 as detailed in the 2009 Kenya Population and Housing Census.

The above population dynamic is mainly for the resident category. The non-resident category comprising of tourists / visitors is considered under the respective contributory Land-Use activities.

### 3.1.2    Population Growth Scenarios

Population trends are influenced by fertility, mortality and migration levels and patterns as well as the national socio-economic development momentum.

Continued rapid growth is expected in the study area considering the infrastructural developments planned for Kilifi Town in the Kilifi County Integrated Development Plan to harness the potential of Kilifi Town for further growth. These factors will result in future immigration and urbanization.

In the last census (2009), it was established that the population within the study area is **41,288**. To forecast the future population up to the design horizon (year 2040), the following factors have been considered:

- Percentage inter census global growth rates within Kilifi County
- The dynamics of Land Use and Trends of development
- The correlation of water demand and income / type of housing, population density etc.

Three population growth rate scenarios have been formulated for the population projection in the study area based on the data obtained from Kenya National Bureau of Statistics, Census Reports and other relevant planning documents. These scenarios are briefly described below;

**High Growth Rate**: This growth rate scenario assumes that the resident population will grow at a higher growth rate than that reported in the last intercensal period i.e. at **5.5%** up to the design horizon of year 2040. This can only happen if the overall natural growth of the resident population continues because of decreased mortality rates and increased life expectancy while immigration gradually increases due to intensive investment in Kilifi Town. Under this scenario, the projected population of Kilifi Town at year 2040 will be **216,675.**

**Medium Growth Rate**: This growth rate scenario assumes that the resident population will grow at a moderate growth rate increasing from **4.0 to 4.6%** up to the design horizon of year 2040. This is comparable to the 4.2% projected for urban growth rate under Millennium Development Goals (MDG's) by 2015. This scenario is possible if the natural growth of the population and influx from immigrants balances out with increased emigrants and mortality rate while growth limiting factors for Kilifi Town such as increased uptake of family planning practices, limited employment opportunities and growth of adjacent peri-urban areas take significance. Thus, the projected population of Kilifi Town at year 2040 under the assumed medium growth rate scenario is **156,254**.

**Low Growth Rate**: This scenario assumes that the population will grow at a rate equivalent to the growth rate in Kilifi Town in the previous intercensal period (1999 - 2009) i.e. **3.01%** up to the design horizon of year 2040. It is assumed that population growth (due to both natural growth rate and immigration) will not increase rapidly due to increase in the uptake of family planning practices, increased mortality and considering that population deflection will take

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

place and the flow of return will be diverted to the development of new adjacent urban areas. Therefore, the population in horizon year 2040 will be **106,165**. This can happen only, if strict measures are taken to control population both in terms of natural growth and in-migration. Based on the experience in the developing world, intensive efforts by government it required to educate people and promote population control measures on one hand and to provide ample economic opportunities in the region to combat in-migration.

Projected populations for the above population growth rate scenarios are given in **Figure 3.1** below;
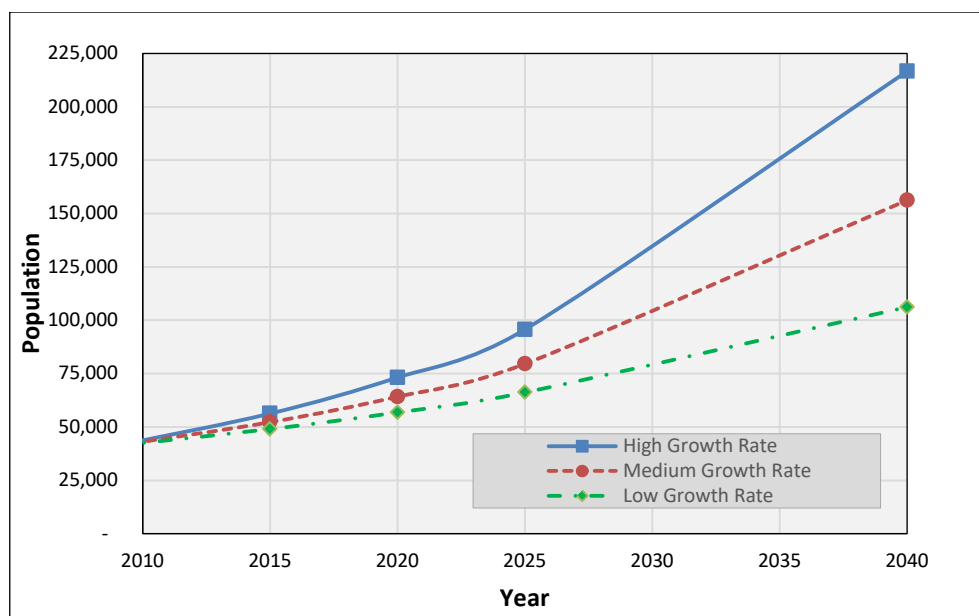


**Figure 3.1: Projected Populations based on Growth Rate Scenarios**

From **Figure 3.1** above, it can be deduced that population forecast is highly sensitive to population growth rate; high growth scenario results to 28% additional population to the medium growth rate scenario while low growth rate scenario results to 32% less the medium growth rate scenario.

### 3.1.3 Projected Population for Kilifi Town

Kilifi is the headquarters of Kilifi County. With the current emphasis of the County as the administrative center under the new devolved structure of the Kenyan Government, population in and around Kilifi is set to grow through an increase in opportunities for employment, investments and improved infrastructure.

Thus, **the medium growth rate scenario scenario considered under the population growth scenario, is the most probable scenario for the future population projections of Kilifi Town up to the 2040 design year.** It considers the demographic dynamics between Kilifi and neighbouring Towns, possible trends in fertility, mortality and migration levels and patterns as well as the socio-economic development. Besides, it has the minimal risk associated under-utilization or over-investments as a result of the population growth deviating from the adopted.

**Table 3.3** on **Page 3-4** gives a summary of the projected population for Kilifi Town up to the design horizon of year 2040, based on the adopted medium growth rate scenario.

**Table 3.3: Summary of the Projected Population**

| Sub-locations | 2009 Pop. | Projected Population | | | |
|---|---|---|---|---|---|
| | | **2015** | **2020** | **2025** | **2040** |
| **Takaungu** | 864 | 1,093 | 1,342 | 1,665 | 3,269 |
| **Mnarani** | 719 | 910 | 1,118 | 1,386 | 2,721 |
| Hospital | 23,663 | 29,941 | 36,779 | 45,615 | 89,553 |
| **Konjora** | 1,324 | 1,676 | 2,058 | 2,553 | 5,012 |
| **Kibarani** | 7,079 | 8,957 | 11,002 | 13,645 | 26,789 |
| **Sokoni** | 2,703 | 3,420 | 4,201 | 5,210 | 10,229 |
| **Mtondia Majaoni** | 4,936 | 6,246 | 7,673 | 9,516 | 18,682 |
| **Total** | **41,288** | **52,241** | **64,173** | **79,590** | **156,254** |

## 3.2    Land Use and Urban Development

### 3.2.1    Introduction

Kilifi Town is a resort Town in the coastal region of Kenya and is the headquarters of Kilifi County. There have been several planning efforts for Kilifi Town with the first Integrated Development Plan prepared in 1981. At that time the Town was at its initial stages of development thus its structure and form was not yet well established and its future growth pattern was uncertain. Urban development was taking place in localised zones such as the town center and adjacent neighborhood of Mtaani - Kisumu Ndogo and sea front at Bofa covering a radius of 4 km$^2$. The other adjacent neighborhoods were growing sporadically. Although Mnarani had already started developing as a satellite neighborhood, it was left out of the planning area boundary due to disputes in land tenure.

Kilifi District Long Term Strategic Development Plan (2001 - 2015) was prepared by Government of Kenya in 2000. The most recent study is the Kilifi County's First Integrated Development Plan     (2013 - 2017) prepared by Kilifi County in 2013. It addresses major development challenges which include poor infrastructure, inadequate skilled labour, low agricultural productivity, environment and climate change, poverty, poor marketing system etc. The plan     outlines development priorities, constraints and strategies in Infrastructure, Energy, ICT, Agriculture, Tourism, Trade, Health, Education, Administration, Socio-cultural issues, Gender, Environmental Protection, Water, Housing, Land Tenure and Mineral Resources.

This Chapter analyzes Kilifi Town in zones borrowing the concept of Uniform Analysis Zones (UAZ). Factors considered in zoning of a Town are sub-locations, administrative function, infrastructure and physical features. Kilifi is divided into the southern and northern zones as delineated by the creek i.e. Zone 1 (Kilifi South) and Zone 2 (Kilifi North). The analysis has been done to inform the preparation of wastewater management needs for period of year 2015 through the year 2040.

Kilifi is expected to continue expanding from the sea side resort town toward the hinterland as population increases. The Mombasa - Garissa Road (Road B8) traverses the County, crossing Kilifi Creek and has been a catalyst of development by joining Kilifi Town to Mombasa and other towns. The development of Pwani University and tourist hotels will spur further increase in population and commercial activities.

### 3.2.2   Existing Land Use

The total Study area of Kilifi is approximately **8,235** ha. The types of land use evident in the Town are: residential, industrial, educational, recreational, transportation, public purpose, public utility, agriculture, hospitality and commercial. The largest portion of land is agricultural covering an area of approximately 5,980 ha which represents 72.62% of the total land, followed by residential land use which covers approximately 1,120ha which represents 13.77% of total land. Recreational land use covers the least portion of land of 3 ha which represents 0.04% of the total land. **Figure 3.2** below shows the existing Kilifi Land Use Plan.
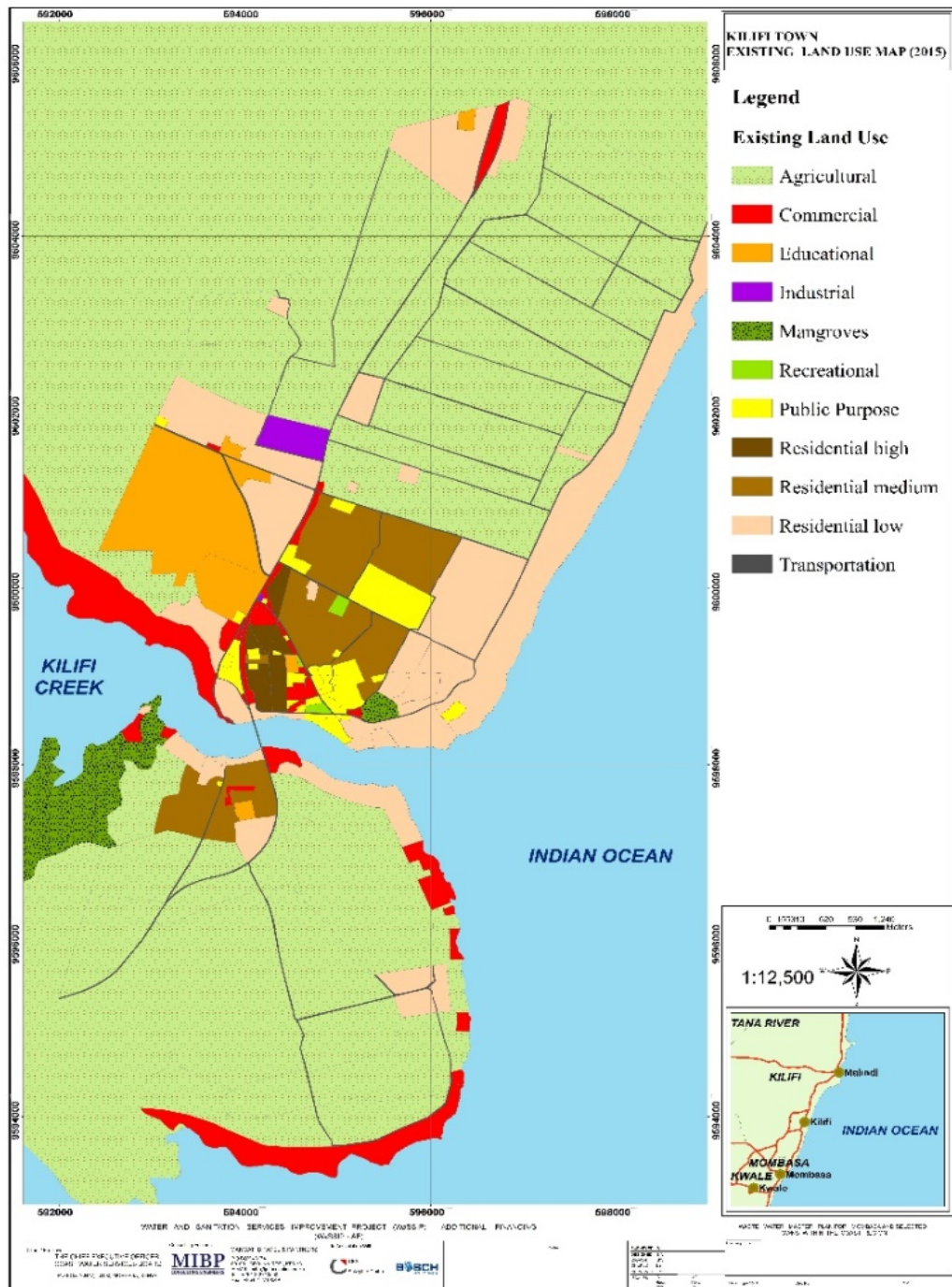


**Figure 3.2: Existing Land Use Map – Kilifi**

**Table 3.4** below shows a summary of existing Land Use of Kilifi.

**Table 3.4:  Summary of Existing Land Use**

| Land Use | Area Covered (Ha) | | Percentage Coverage (%) |
|---|---|---|---|
| | Kilifi South Zone 1 (Area Ha) | Kilifi North Zone 2 (Area Ha) | |
| Residential | 178 | 942 | 13.77 |
| Industrial | - | 26 | 0.31 |
| Educational/ Institutional | 4 | 239 | 2.98 |
| Recreational | - | 3 | 0.04 |
| Public/ Special Purpose | - | 102.88 | 1.25 |
| Commercial | 124 | 196 | 3.89 |
| Transportation | 20 | 93 | 1.37 |
| Agriculture | 1,863 | 4,117 | 72.62 |
| Mangroves | - | 221.08 | 2.68 |
| Open Space | - | 106 | 1.29 |
| **Total** | **2,189** | **6,046** | **100** |

The main drivers of growth in Kilifi Town are as follows:

**i)   Tourism**

Kilifi Town is a popular Tourist destination with major attractions being the white sandy beaches of the Indian Ocean and the Kilifi Creek. The coastline is characterised by resorts, hotels and other entertainment centres. The tourism sector plays a key role in socio-economic growth in Kilifi Town. It creates employment opportunities to the local community and in addition is the main source of Government Revenue in Kilifi.

**ii)   Agriculture and Industry**

Kilifi County has potential to grow its agricultural production with the available large tracts of arable land, fertile soils and favourable climate. The agricultural sector provides food and creates employment opportunities which minimizes poverty levels in Kilifi Town. A good example is cashew nuts which are a major cash crop in Kilifi. The Mombasa-Garissa highway traverses Kilifi provides an efficient link to food markets in nearby towns. Food processing industries are developing due to the availability of raw materials, labour and market. Implementation of the strategies in the County Development Plan for development of the agricultural sector will steer socio-economic development of Kilifi Town.

**iii)   Mombasa - Garissa Road**

The Mombasa - Garissa Road (Road B8) starts in Mombasa and traverses through several Counties to end at Garissa Town. This road helps to connect Kilifi County to other towns and providing access to tourist hotels and other businesses in Kilifi. The road also enables efficient transport of agricultural produce from Kilifi to other towns.

**iv)   Administrative Function**

Kilifi town is the headquarters of Kilifi County and with the devolved Government structure, the town is experiencing development of physical and social infrastructure for service provision. The improved infrastructure will attract investment in tourism, industrial, agricultural and trade sectors which will increase employment opportunities to the local community.

The main physical constrains of growth for Kilifi Town are:

a) Land Tenure - Kilifi South is less developed than Kilifi North due to the lack of clear land tenure systems in Kilifi South. The National Government and Kilifi County Government should address the situation and issue Title Deeds to provide security of tenure and encourage investments.

### 3.2.3    Land Use Planning and Policy

All Land-Use activities depend on the regulations and practices that govern land ownership. Land allocation and ownership require proper planning for optimal utilisation.

Land-use planning encompasses the systematic social and economic assessment of land and water potential including the alternative land-uses for the selection and adoption of the best land-use options. It seeks to regulate land-use in efficient and ethical way and prevent land-use conflicts. Land-use planning is practiced to manage the development of land within jurisdictions, plan for the needs of the community and safe-guard the natural resources. Land-use planning often lead to land-use regulations, which typically encompasses zoning.

Zoning regulates the type of activities that can be accommodated on a piece of land, as well as the amount of space devoted to those activities and the ways that buildings may be situated and shaped. Conventional zoning does not regard the way buildings relate to one another or the public spaces around them, but rather provide a pragmatic system for mapping jurisdictions per permitted land use.

The primary purpose of zoning is to segregate uses that are thought to be incompatible. In practice, zoning is used to prevent new developments from interfering with the existing land-use activities and to preserve the "character" of an area. Zoning is commonly controlled by the local governments such as County Governments, though the nature of the zoning regime may be determined or limited by the national planning authorities or through enabling legislation.

Zoning may include regulation of the kinds of activities which will be acceptable on particular plots (such as Open Spaces, Residential, Agricultural, Commercial or Industrial), the densities at which those activities can be performed (from Low-Density Housing such as Single Family Homes to High-Density such as High-Rise Apartment Buildings), the height of the building etc.

The projected populations including **156,254** in **Year 2040** (Refer to **Table 3.3** on **Page 3-4**) are proposed to be accommodated within the coverage of Kilifi study area. It is also proposed that the existing vacant land be utilised including the range lands where the slope is gentle for development to accommodate part of the projected population.

### 3.2.4    Land Use Requirement per Land Use Zone

Land requirement in zoning depends on projected population, proposed landuse and proposed population density.

In the Kilifi study area at present and as projected in year 2040, agricultural land-use has the highest land requirement and residential land-use is the second largest land-use. Areas currently under agricultural and residential low and medium density landuse will be converted to commercial and medium to high density residential areas to accommodate the projected year 2040 population of Kilifi Town. Details of the projected additional land requirement for each landuse is given in **Table 3.5** on **Page 3-9**.

The proposed population densities for each category of Residential Land-use have been worked out based on the projected population, land available for future development, potential for densification in already developed area and trend and experience in Towns of similar nature and keeping sufficient room within the current planning boundary for future urban expansion i.e. beyond year 2040.

Details of existing land use and projected land requirement are given in **Table 3.5** below.

**Table 3.5: Existing Land Use and Projected Land Requirement**

| Land Use | Existing Land Use 2015 | | Increased Land Use 2025 | | Increased Land Use 2040 | |
|---|---|---|---|---|---|---|
| | Kilifi South Zone 1 (Area Ha) | Kilifi North Zone 2 (Area Ha) | Kilifi South Zone 1 (Area Ha) | Kilifi North Zone 2 (Area Ha) | Kilifi South Zone 1 (Area Ha) | Kilifi North Zone 2 (Area Ha) |
| Agricultural | 1,863 | 4,117 | - | - | - | - |
| Commercial | 124 | 196 | 145 | 199 | 151 | 200 |
| Educational | 4 | 239 | 10 | 279 | 32 | 301 |
| Industrial | - | 26 | - | 30 | - | - |
| Public purpose | 0.3 | 103 | 1.3 | 123 | - | 127 |
| Recreational | - | 3 | - | 5 | - | 6 |
| Residential high | - | 43 | - | 50 | - | 62 |
| Residential medium | 72 | 213 | 87 | 261 | 94 | 273 |
| Residential low | 106 | 686 | 120 | 761 | 125 | 787 |
| Open space | - | 105.88 | - | - | - | - |
| Transportation | 20 | 93 | - | - | - | - |
| Conservation/ Mangroves | - | 221.08 | | | | |
| **Total** | **2,189** | **6,046** | **364** | **1,709** | **402** | **1,756** |

Kilifi North is more developed than Kilifi South. Development in Kilifi South is hindered by the historical issues with security of Land Tenure. Lack of Title Deeds by most residents slows down the development of large residential and commercial investments. As the security of land tenure is provided, development would increase in Kilifi South.

Kilifi Town lacks a specific Integrated Strategic Urban Development Plan (ISUDP) which is essential for a sustainable and orderly development through consolidation and reservation of land for future use. With implementation of the ISUDP, the projected Land-use detailed in Table 3.5 above can be attained. The ISUDP should also aim at enforcing development control, establishing adequate, decent and affordable housing, conservation of the green spaces and the environment and also provide a road map for provision of services and facilities.

In the Proposed Land-use plan, Kilifi Study area, Agricultural Land-use will still be predominant, however, agricultural land in the periurban areas will be converted to residential, commercial and industrial land-use as Kilifi Town develops.

A Layout Plan showing the Proposed Land Use for Year 2025 and Year 2040 is given in **Figure 3.3** on **Page 3-9**.

**Table 3.6** on **Page 3-10 to 3-13** shows a summary of adoptive standards for Urban Planning.

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

**FINAL MASTER PLAN REPORT**
**KILIFI TOWN**
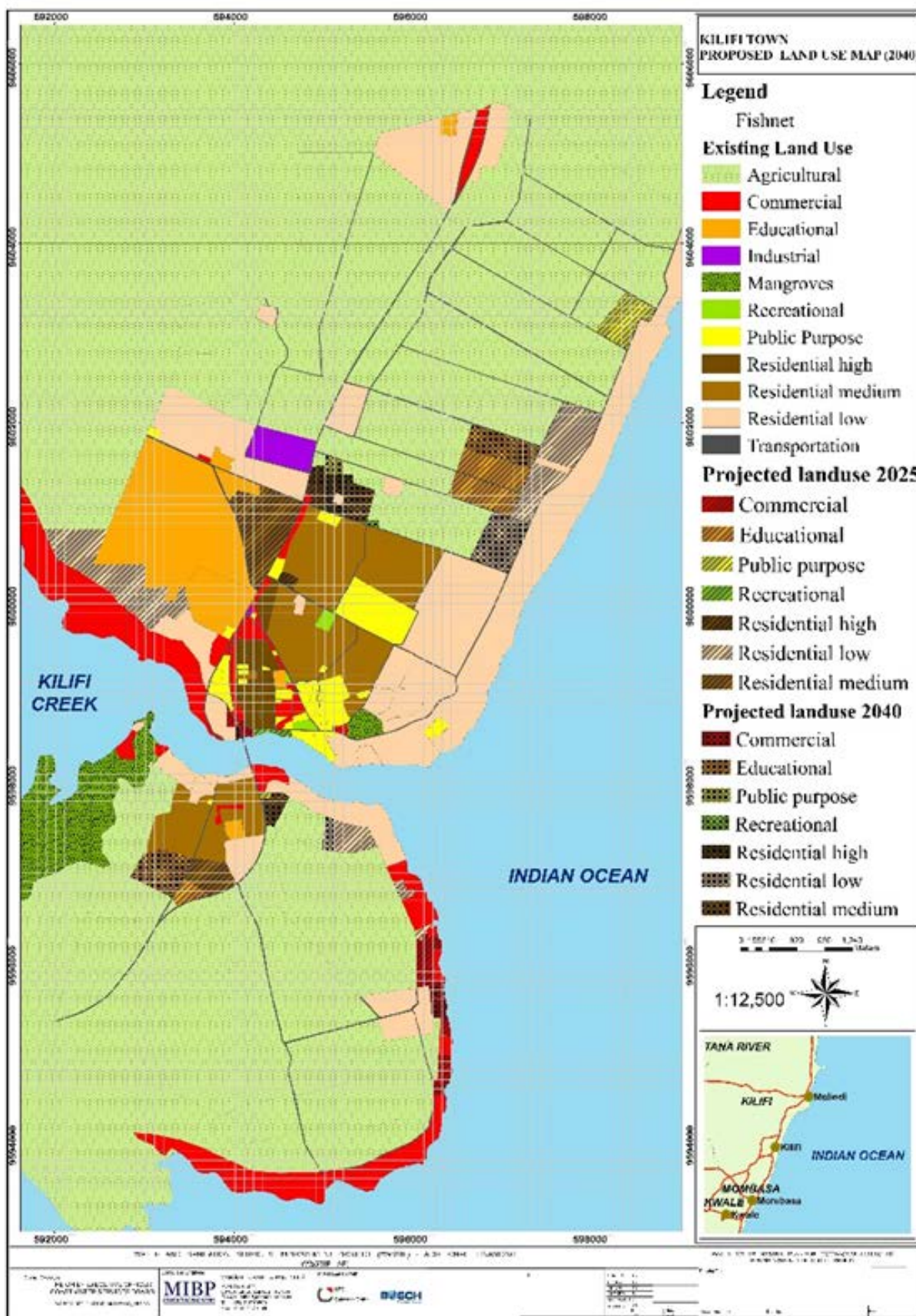
**Figure 3.3: Existing Land Use (Year 2015) and Projected Land Use (Year 2025 and 2040)**

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

**Table 3.6 : Adoptive Standards for Urban Planning**

| Zone O: | Residential | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 0 | Residential | Bungalows | 35 | 25 | 0.4 Ha | Low Density | Single Dwelling Units | |
| | Residential | Bungalows | 35 | 25 | 0.4 Ha | Low Density | Single Dwelling Units | Cottage industry may be practised |
| | Residential | Bungalows | 35 | 25 | 0.4 Ha | Low Density | Single Dwelling Units | A Secondary School may be developed at an appropriate site |
| | Residential | Bungalows, | 25 | 25 | 0.2 Ha | Medium density | Single Dwelling Units | |
| | Residential | Bungalows, | 25 | 25 | 0.2 Ha | Medium density | Single Dwelling Units | |
| | Residential | Maisonettes Town houses Duplexes | 50 50 | 50 | 0.1 Ha | Low Medium density | Two residential units allowed per plot | Shops allowed on plots fronting 9 m roads |
| | Residential | Maisonettes Town houses Duplexes | 50 50 | 50 | 0.1 Ha | Low Medium density | Two residential units allowed per plot | Shops allowed on plots fronting 9 m roads |
| | Residential | Maisonettes Town houses Duplexes | 50 50 | 50 | 0.1 Ha | Low Medium density | Two residential units allowed per plot | Shops allowed on plots fronting 9 m roads |
| | Mixed developments | Town houses Duplexes Swahili houses Guest/Boarding houses | 65 | 65 | 0.03 - 0.045 | High Density | Multiple residential units allowed | Shops allowed on plots fronting 9 m roads |
| | Mixed developments | Town houses Duplexes Swahili houses Guest/Boarding houses | 65 | 65 | 0.045 | High Density | Multiple residential units allowed | Shops allowed on plots fronting 9 m roads |
| | Mixed developments | Town houses Duplexes Flats Swahili houses Guest/Boarding | 65 | 65 | 0.03 - 0.045 | High Density | Mixed house types allowed | Upgrading areas |

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

| Zone 1: Industrial | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 1 | Industrial | Industrial plant | 50 | 150 | 0.2 | N/A | N/A | |
| | Light Industry | Repair Workshops, Hardware stores Furniture Makers small tin smiths, Re-use Industries | 50 | 75 | 0.045 | N/A | Garages, furniture and welding workshops allowed | |
| | Light Industry | Godowns, warehouse, hardware stores | 50 | 75 | 0.045 | N/A | Garages, furniture and welding workshops allowed | |
| Zone 2: Educational | | | | | | | | |
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 2 | Educational | Classes, offices and dormitories Sanitation block | 10 | 30 | Nursery Sch.  0.1 Pri. school     4.0 Sec. School    4.5 College        10.2 University     50.0 | N/A | N/A | Storeyed buildings recommended for effective use of space Sharing of recreational facilities recommended Institutional Housing allowed |
| Zone 3: Recreational | | | | | | | | |
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 3 | Recreation | Conservation/ Green Park | | | | | | |
| | Recreation | Conservation/ Green Park | | | | | | |
| | Recreation | Conservation/ Green Park | | | | | | |

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

| Zone 4: Public purpose | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 4 | Government Headquarters | Civic offices: - County government; local authorities, parastatals, trade unions, political party offices, library entertainment, etc. | | | | | | Spatial compactness Public parking Accessibility |

| Zone 5: Commercial | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 5 | Commercial | Compatible mixed use | 75 | 600 | 0.045 | N/A | Commercial | Densification and diversification recommended Flats and high rise buildings recommended Future commercial core |

| Zone 6: Public Utilities | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 6 | | | | | | | | |
| | | | | | | | | |

| Zone 7: Transportation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Proposed Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 7 | Lorry park | | N/A | N/A | 2 | N/A | N/A | To be developed through public private partnership |
| | Bus park | | | | | | | To be developed by County Government |

| Zone 8: Hospitality Zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Future Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| 8 | | | | | | | | |

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Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

| Zone 9: Agriculture | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zone | Future Land Use | Types of Development Allowed | BCR | PR | Min Plot Size | Density of Development | No. of Dwelling Units | Other Requirements |
| LD | Residential | Bungalows | 35 | 25 | 0.4 Ha | Low Density | Single Dwelling Units | Agriculture may be practised |
| | Residential | Bungalows | 35 | 25 | 0.4 Ha | Low Density | Single Dwelling Units | Agriculture may be practised |
| | Residential | Bungalows | 35 | 25 | 0.4 Ha | Low Density | Single Dwelling Units | Agriculture may be practised |
| MLD | Residential | Bungalows, | 25 | 25 | 0.2 Ha | Medium density | Single Dwelling Units | |
| | Residential | Bungalows, | 25 | 25 | 0.2 Ha | Medium density | Single Dwelling Units | |
| | Residential | Bungalows, | 25 | 25 | 0.2 Ha | Medium density | Single Dwelling Units | |
| | Residential | Maisonettes Town houses duplexes | 50 50 | 50 | 0.1 Ha | Low Medium density | Two residential units allowed per plot | Shops allowed on plots fronting 9 m roads |
| | Residential | Maisonettes Town houses duplexes | 50 50 | 50 | 0.1 Ha | Low Medium density | Two residential units allowed per plot | Shops allowed on plots fronting 9 m roads |

## 4.0  WATER DEMAND FORECAST

Water demand is defined *as "the volume of water different categories of consumers can afford to consume in a context of unrestricted supply"*. The water demand of an area is dependent on the climate, economic considerations, sanitation facilities, industrial and commercial requirements.

**Water demand**
$$= \text{Domestic demand} + \text{Institutional demand} + \text{Commercial demand} + \text{Industrial demand} + \text{Tourism Recreation demand}$$

For a more accurate determination of the total water demand, it is important to adopt accurate water consumption rates for each of the above water demand categories.

### 4.1  Analysis of Water Consumption Rates

The Design Manual for Water Supply in Kenya (MWI, 2008) gives guiding values of water consumption rates for the various categories of Water Demand. However, from individual studies and in consideration of various local conditions, several Consultants have adopted varied water consumption rates for the determination of Water Demand in Kilifi Town.

A summary of the Studies / Designs prepared by the various Consultants for Water Supply in Kilifi Town and other Coast Towns is given below:

- Tahal Group and Bhundia Associates finalised the Water Supply Master Plan for Mombasa County and selected Towns in year 2013.
- Egis/bceom/Mangat JV finalised the Detailed Design of Rehabilitation and Expansion for Mombasa Water Supply and Sewerage System in year 2011.
- Gauff JBG/ TRAQ Consulting Engineers Detailed Design Report for Kilifi Water Service Provider, October 2010.
- Suereca / Mangat finalised Second Mombasa & Coastal Water Supply Project, Final Design Report, January 1998
- Kittelberger Consult GmbH Consulting Engineers Joint Venture with Mangat, I.B. Patel & Partners finalised Malindi Sanitation & Hygiene Education Feasibility Study in year 1994
- Norconsult A.S. Consulting Engineers finalised the Malindi Sewerage Master Plan and Preliminary Design Storm Water Feasibility Study, November 1978.

A comparison of water consumption rates adopted in the above Studies / Designs including those recommended in the Practice Manual for Water Supply Services in Kenya is given in **Table 4.1** on **Page 4-2**.

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL MASTER PLAN REPORT
KILIFI TOWN

**Table 4.1: Comparison of Water Consumption Rates**

| Consultant | Name of Report | Domestic Water consumption (l/c/day) | | | Institutions Water Consumption | | | Commercial Water Consumption (l/head/day) | Industrial Water Consumption (l/Ha/day) |
|---|---|---|---|---|---|---|---|---|---|
| | | Low Density | Medium Density | High Density | Boarding Schools (l/head/day) | Day Schools with WC (l/head/day) | Regional Hospitals (l/bed/day) | | |
| Tahal Group / Bhudia Associates | Water Supply Master Plan for Mombasa and other Towns - Aug 2013 | 250 | 150 | 75 | - | - | - | - | - |
| Egis Bceom / Mangat | Rehabilitation & Expansion of Mombasa Water Supply & Sewerage Project - Final Design Report - July 2011 | 250 | 100 | 60 | - | - | - | 6 | 25.000 |
| Gauff JBG / TRAQ | Detailed Design for Malindi Water Service Provider – Oct 2010 | 200 | 120 | 60 | 100 | 20 | 365 | 83 | 30,000 |
| Seureca / Mangat | Second Mombasa and Coastal Water Supply Project Final Design Report - January 1998 | 200 | 80 | 70 | 50 | 25 | 700 | 5 | 20,000 |
| Kittelberger Consult GmbH Joint Venture with Mangat, I.B. Patel & Partners | Malindi Sanitation and Hygiene Education Feasibility Study - March 1994 | 300 | 150 | 75 | 50 | 25 | 400 | 25 | 29,400 |
| Norconsult S.A Consulting Engineers | Malindi Sewerage Master Plan and Preliminary Design Storm Water Feasibility Study - November 1978 | 300 | 150 | 75 | 50 | 25 | 400 | - | 15,000 |
| Ministry of Water & Irrigation | Practice Manual for Water Supply Services in Kenya | 250 | 150 | 75 | 50 | 25 | 400 | - | 20,000 |

After analysis of these water consumption rates indicated in **Table 4.1** on **Page 4.2**, the water consumption rates adopted in this Study for the various consumer categories are described below:

a) **Residential Water Demand**

From the findings by different Consultants, it is evident that the type of housing and mode of water supply are relevant indicators for classifying domestic consumers.

Based on per capital demand observed in similar socio economic and climatic context but without restriction of water supply, the Consultant proposed to adopt the following consumption rates for each category of domestic consumer as summarised in **Table 4.2** below.

**Table 4.2: Adopted Housing Categories & per Capita Water Consumption**

| Category | Description | Consumption Rate (l/c/d) |
|---|---|---|
| Low Density | Residential Houses and Maisonettes | 200 |
| Medium Density | Flats and Estates | 120 |
| High Density | Traditional Houses (Informal Settlements and Swahili houses | 60 |

b) **Institutional Water Demand**

The institutional water demand was calculated based on the following commonly accepted demand criteria by type of institution:

- Boarding Schools              -        50 l/head/day
- Day School with WC            -        25 l/head/day
- Regional Hospital             -        200 l/bed/day plus 5,000 l/day
- Dispensary and Health Centre  -        5,000 l/day
- Administrative Offices        -        25 l/head/day

c) **Commercial Water Demand**

The commercial water demand was calculated based on the following commonly accepted demand criteria by type of commercial facility:

- Shops                         -        100 l/day
- Bars                          -         500 l/day

d) **Industrial Water Demand**

The following criteria was adopted for the industrial water demand based on commonly accepted demand criteria: -

- Intensive industrial activity    -     25,000 l/day/ha
- Small scale industrial activity  -     600 l/day/ha

e) **Tourism Water Demand**

The following criteria was adopted for tourism demand based on commonly accepted demand criteria:

- Four and five star hotels     -        600 l/occupied bed/ day
- Other hotels                  -        300 l/occupied bed/ day
- Tourist cottages complexes    -        200 l/occupied bed/ day

### 4.2    Water Demand Projections

The water demand for Kilifi Town is expected to increase over the design period (up to 2040) due to the projected increase in population, commerce and industrialization. The major drivers for this development include the tourism industry, improved infrastructural network within the rest of the County and potential for new settlements.

The water demand by consumer category for the Design Horizons 2025 and 2040 has been calculated based on the projected population and proposed future land-use.  A summary of the water demand by sub-location for Design Horizons Year 2025 and Year 2040 is given in **Tables 4.3** and **4.4** below.

**Table 4.3: Water Demand for Medium Term Plan Horizon - Year 2025**

| Sub-Location | Water Demand (m³/d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Domestic** | **Health** | **Education** | **Recreational** | **Commercial** | **Industrial** | **Total** |
| Takaungu | 186 | 4 | 6 | 2 | 3 | 3 | 204 |
| Mnarani | 154 | 4 | 5 | 2 | 3 | 3 | 171 |
| Hospital | 5,086 | 118 | 156 | 58 | 83 | 84 | 5,585 |
| Konjara | 284 | 7 | 9 | 3 | 5 | 5 | 313 |
| Kibarani | 1,520 | 35 | 47 | 17 | 25 | 25 | 1,669 |
| Sokoni | 580 | 13 | 18 | 7 | 9 | 10 | 637 |
| Mtondia Majaoni | 1,060 | 25 | 33 | 12 | 17 | 18 | 1,165 |
| **Total** | **8,870** | **206** | **274** | **101** | **145** | **148** | **9,736** |

**Table 4.4: Water Demand for Long Term Plan Horizon - Year 2040**

| Sub-Location | Water Demand (m³/d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Domestic** | **Health** | **Education** | **Recreational** | **Commercial** | **Industrial** | **Total** |
| Takaungu | 364 | 8 | 11 | 4 | 6 | 6 | 399 |
| Mnarani | 303 | 7 | 9 | 4 | 5 | 5 | 333 |
| Hospital | 9,976 | 231 | 306 | 114 | 162 | 166 | 10,955 |
| Konjara | 558 | 13 | 17 | 6 | 9 | 9 | 612 |
| Kibarani | 2,984 | 69 | 97 | 34 | 49 | 50 | 3,283 |
| Sokoni | 1,139 | 26 | 35 | 13 | 19 | 19 | 1,251 |
| Mtondia Majaoni | 2,081 | 48 | 64 | 24 | 34 | 35 | 2,286 |
| **Total** | **17,405** | **402** | **539** | **199** | **284** | **290** | **19,115** |

The water demand projection for Kilifi Town is shown in **Figure 4.1** on **Page 4-5**.
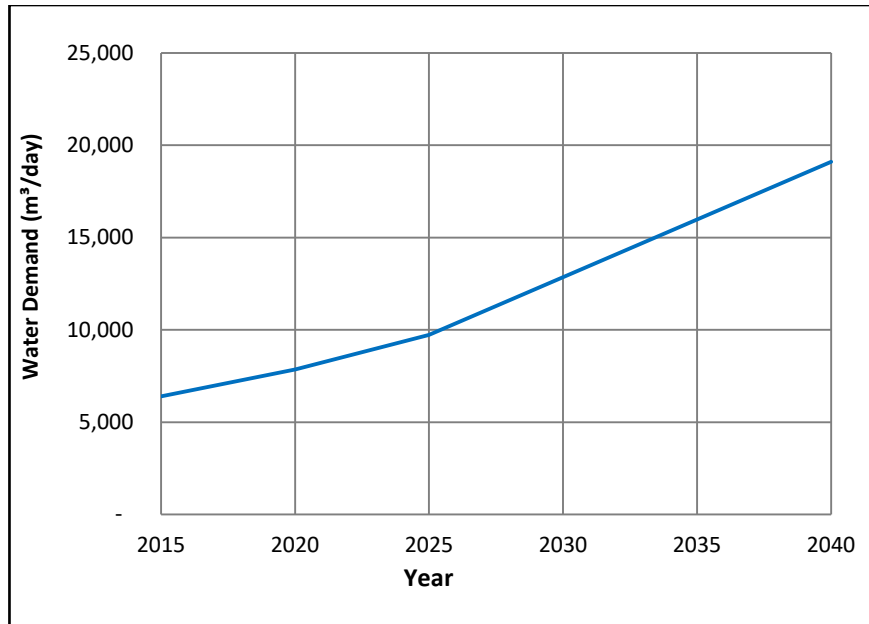
**Figure 4.1: Water Demand Projection**

## 5.0    WASTEWATER FLOW PREDICTIONS

### 5.1    Design Criteria

The determination of the wastewater flows to be used in the design of the Sewerage System, Pumping Stations and Waste Water Treatment Plant for Kilifi Town has been guided and based on the Standard design criteria described in the following sub-sections;

### 5.1.1    Principal References

In Kenya, it is a standard practise to refer to the Design Manuals prepared by the Ministry of Water and Irrigation for the design of Sanitation Projects.

The principal References used to formulate the design criteria for Kilifi Town are as follows;

- Practice Manual for Sewerage & Sanitation Services in Kenya, December 2008 - Ministry of Water & Irrigation
- Selection and Design Criteria for Sewerage Project, Report No. 9 - World Health Organisation (WHO Report No. 9)
- Nairobi City Council - Sewer Design and Construction - Parameters for Adoptive Standards, 1974 (Nairobi City Council Manual)
- The Design of Small Bore Sewer Systems by Richard J. Otis and D, Duncan Mara (1985)
- Domestic Wastewater Treatment in Developing Countries by D. Duncan Mara (2003)

The Criteria outlined in these principal References have been evaluated in the context of the Consultants experience, knowledge and complemented with local and internationally accepted design standards.

### 5.1.2    Sewerage Collection System

As outlined in WHO Report No. 9, there are three forms of sewerage collection systems, namely;

- *Separate Systems:* Storm water and wastewater are collected and transported in two separate systems. Ideally, no storm water is allowed into the sanitary sewers.
- *Combined Systems:* Storm water and wastewater from premises are collected and transported in one system. In this system, only one network of pipes is provided and those pipes are designed to carry both wastewater flows and storm water.
- *Partially Separate Systems:* With these systems, the sewerage collection system is designed to carry all the wastewater together with some storm water.  The bulk of the storm water is collected in an independent system of pipes and open drains.

From the TOR "*Neither CWSB nor the WSPs have the responsibility for the provision or maintenance of storm water drainage systems and so the study and review of those facilities is not included in this Wastewater Master Plan Study. All sewers shall be designed for separate systems.*"

In line with the TOR, a separate sanitary sewer system has been proposed for the design of the Trunk and Secondary Sewers in Kilifi Town.

### 5.1.3    Sewage Generation

Waste water collected in the Sewerage System is generated from;

- Domestic, institutional and Commercial consumers
- Industrial Effluent
- Infiltration and Inflow into the Sewerage System

### 5.1.3.1 Domestic and Commercial Consumers Sewage Contribution Factor

Not all the water supplied to a premise will reach the sewers as wastewater. The flow of wastewater leaving premises is dependent on following;

- Quantity of water supplied to the building
- Characteristics of the housing type
- Climate with higher losses associated with arid conditions
- Ground conditions with higher losses associated with high ground porosity

The figure normally varies from 75% to 85% of water supplied, to different categories of consumers as outlined in WHO Report No.9 and summarised in **Table 5.1** below**.**

**Table 5.1: Portion of Water Used that ends up as Wastewater**

| S/No. | Category | Wastewater generated as a Percentage of water supplied (%) |
|-------|----------|------------------------------------------------------------|
| 1 | High Income Housing | 75 |
| 2 | Medium Income Housing | 80 |
| 3 | Low Income Housing | 85 |
| 4 | Communal ablution/ latrine block | 85 |
| 5 | Day schools, shops and offices | 85 |
| 6 | Other Institutions | 80 |

The Study adopts an overall figure of 80% for the sewage contribution factor in consideration that it has become a standard practice to adopt 80% in the design of Sewerage Systems for othe Towns in Kenya.

### 5.1.3.2 Industrial Effluent

Industrial effluent generation varies from industry to industry and therefore, each individual factory on a Sewerage System must be considered separately. However, for areas designated for future industries whose type is not known, WHO Report No. 9 recommends a rate of 25,000 l/ha/day. This has been adopted in the Study.

### 5.1.3.3 Infiltration and Inflow

The design of the sewers is based upon the concept of a separate Sewer System, i.e. sewers that are designed to carry only the anticipated sewage flows with only a nominal allowance in the pipe capacity for infiltration and storm-water inflow.  If significant amounts of water from these other sources are allowed into the sewers, then the sewers will be 'robbed' of their carrying capacities, treatment plants of their process performance capabilities and the pumping costs will increase significantly.  However, a small amounts of water still enters the sewers from other sources, normally referred to as infiltration and inflow.

**Infiltration** is defined as the water entering a Sewer System from below ground level through such means as defective pipes, joints, connections or manholes.

The rate of infiltration into sewer pipes depends generally on the depth of the water table, sub-soil conditions, workmanship during construction, age and condition of the pipes and the frequency of occurrence of improper connections. Another significant factor can be the condition and depth of manholes, damaged or missing covers or where the ground surface level is above cover level, then surface water runoff can enter the sewer as inflow.

For the design of the sewers in Kilifi Town, it is intended to use an infiltration allowance that is based upon the area contributing to the sewer. This Study adopts the recommendation of Nairobi City Council manual of a constant infiltration rate of 0.0025 l/s/ha within the design coverage area.

**Inflow/Splash** is defined as the storm-water discharged into a Sewer System from above ground from such sources as roofs/ yards through inspection chambers within premises, open/loose manhole covers, cross connections from storm drains, etc.

In addition to infiltration, Nairobi City Council Manual also recommends the use of a "Splash Allowance", which is in effect, make an allowance for unavoidable storm water entry and for authorised drainage of open industrial and commercial areas, i.e. "inflow". This allowance is taken as a percentage of the domestic wastewater flow and ranges from 5% to 30% depending upon the predominant housing type i.e.

- 30% for low income housing
- 15% for medium income housing
- 10% for high income housing

A conservative value of 5% of the total wastewater flow has been adopted in this Study for the determination of Splash flow contribution.

### 5.1.4    Peak Flow Factor and Sewer Capacity

A sewer should be designed to handle the peak sewage flows that occur due to daily, diurnal and seasonal fluctuations. A peak factor, which refers to an estimated ratio of maximum to average sewage flow, is applied on the average wastewater flow is used to determine the peak flow.

Sewers are normally designed to flow half full at peak flow, where peak dry weather flow is defined as:

Peak Dry Weather Flow, PDWF        =        FR (DWF-I) + I

Where:

| | | |
|---|---|---|
| PDWF | = | Peak Dry Weather Flow (l/s) |
| FR | = | Peak Factor |
| DWF | = | Dry Weather Flow (Design Flow) (l/s) |
| I | = | Infiltration Rate (l/s) |

The Dry Weather Flow (Design Flow), which includes allowance for inflow and infiltration can be calculated from:

$$\text{DWF} = \text{SF}\left[\left(\frac{P \times G}{86400}\right) \times \left(\frac{1+SA}{100}\right) + \frac{E \times A_E}{86.4} + I_R(A_P + A_E)\right]$$

Where:

| | | |
|---|---|---|
| SF | = | Sewage Reduction Factor (%) |
| P | = | Population (no. of persons) |
| G | = | Water Consumption (litres per person per day) |
| SA | = | Inflow/Splash Allowance as % of P x G (litres per day) |
| E | = | Industrial Waste Water Flow (m$^3$/ha/day) |
| $A_E$ | = | Industrial Drainage Area (Ha) |
| $I_R$ | = | Infiltration Water Flow Rate (l/sec/ha) |
| $A_P$ | = | Domestic Drainage Area (Ha) |

The daily peak flow in a sewer is a function of the area contributing to the sewer, which, in turn, determines the contributing population and hence the size of the pipe.  An increase in the contributing area results in a lower peak factor, hence large trunk sewers have lower peaks than small branch sewers.

Many methods and formulae are used to predict peak factors in sewers. The factors derived by Nairobi City Council in the 1960s, after a comprehensive survey of the Capital City's sewers, are shown in **Table 5.2** below.

**Table 5.2: Nairobi City Council Manual Peak Flow Factors**

| DWF (litres/sec) | Peak Factor |
|---|---|
| < 6 | 7.5 |
| < 12 | 6.6 |
| < 60 | 5.5 |
| < 120 | 5.0 |
| < 600 | 3.8 |
| > 600 | 3.1 |

These Peak Flow factors are considerably higher than those resulting from the empirical formulas commonly used. Some of the commonly used formulas are given in **Table 5.3** below.

**Table 5.3: Common Formulas used to calculate Peak Flow Factor**

| | |
|---|---|
| Legg Formula, for population     < 7,000 Persons | $Peak\ Factor = \dfrac{6.51}{Population^{0.38}}$ |
| Babbit Formula, for population   < 7,000 Persons | $Peak\ Factor = \dfrac{5}{Population^{0.2}}$ |
| Harmon Formula, for population > 7,000 Persons | $Peak\ Factor = 1 + \dfrac{14}{4 + Population^{0.5}}$ |

Recent studies of the flow records in Nyeri Town carried out by the Nyeri Water & Sewerage Company indicate that the Babbitt Formula gives peak factors that more accurately correspond to the measured peaks in the Sewerage System.

The empirical formulas adopted in the computation of peak flows for Kilifi Town are as follows;
- Babbit formula for populations less than 7,000 persons
- Harmon Formula for populations greater than 7,000 persons

## 5.2      Projected Wastewater Flows

The total wastewater generated within a service area is determined by the wastewater generated from the water consumed (sewage contribution factor of 80%), infiltration into the sewers and splash flows.

Based upon the above components and assuming a regular/unsuppressed water supply and full water distribution network, the projected wastewater generation for the sub-locations covered by the study area of Kilifi Town has been determined and are given in **Table 5.4** below;

**Table 5.4: Projected Wastewater Generation up to Year 2040**

| Sub-Location | Area (Ha) | Wastewater Generation (m³/d) | | | | |
|---|---|---|---|---|---|---|
| | | **2009** | **2015** | **2020** | **2025** | **2040** |
| Takaungu | 195 | 108 | 131 | 157 | 190 | 355 |
| Mnarani | 190 | 90 | 109 | 131 | 158 | 295 |
| Hospital | 1,167 | 2,951 | 3,596 | 4,299 | 5,207 | 9,722 |
| Konjara | 649 | 165 | 201 | 241 | 291 | 544 |
| Kibarani | 96 | 883 | 1,076 | 1,286 | 1,558 | 2,908 |
| Sokoni | 440 | 337 | 411 | 491 | 595 | 1,110 |
| Mtondia Majaoni | 1,460 | 616 | 750 | 897 | 1,086 | 2,028 |
| **Total** | **4,198** | **5,149** | **6,275** | **7,501** | **9,085** | **16,963** |

However, achieving conditions of regular / unsuppressed water supply and full sewer connections in a Town with Sewerage System is nearly impossible. This is due to limited development of water resources to supply Kilifi Town, inadequate water distribution and sewerage networks and the use of on-plot sanitation systems due to topography, affordability, unplanned settlements, etc.

To consider the above situation, the factors of Sewer Connectivity and Water Supply, given in **Tables 5.5** and **5.6** below, have been adopted for the formulation of realistic wastewater generation projection for Kilifi Town.

**Table 5.5: Sewer Connectivity adopted for Realistic Wastewater Generation Projection**

| Population Category Based on Income Levels | Sewer Connections | |
|---|---|---|
| | 2021 - 2030 | 2031 - 2040 |
| High Income | 20% | 80% |
| Medium Income | 100% | 100% |
| Low Income with Individual Water Connection | 60% | 80% |
| Low Income without Individual Water Connection | 30% | 40% |

**Table 5.6: Water Supply Status adopted for Realistic Wastewater Generation Projection**

| Population Category Based on Income Levels | Water Supply Status as a % of Regular Water Supply | |
|---|---|---|
| | 2021 - 2030 | 2031 - 2040 |
| High Income | 50% | 80% |
| Medium Income | 50% | 80% |
| Low Income with Individual Water Connection | 50% | 80% |
| Low Income without Individual Water Connection | 50% | 80% |

**Figure 5.1** below shows the projected wastewater flows up to Year 2040 for the ideal conditions of regular water supply and sewer connection condition (100% Sewer Connections) and the realistic conditions of suppressed water supply and gradual implementation of sewer connections;
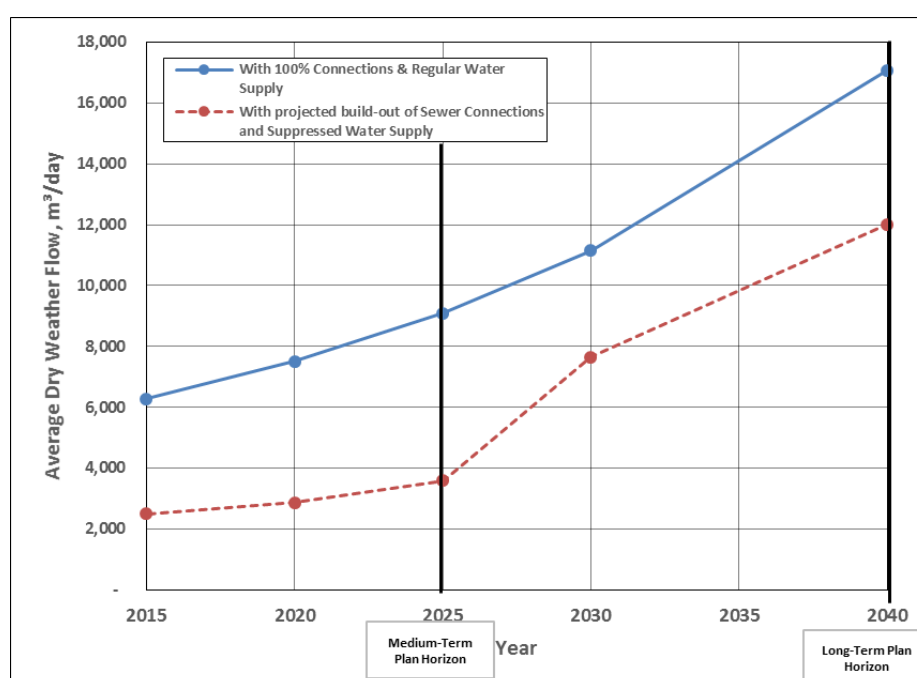


**Figure 5.1: Projected Wastewater Flows up to Year 2040**

From **Figure 5.1** on **Page 5-5**, the projected wastewater generation based on the realistic conditions of water supply and sewer connections at the Years 2025 and 2040 is 3,800 m³/day and 12,000 m³/day respectively.

**The design of the Wastewater Treatment Plant and Sewerage System have been based on the wastewater flow generation determined from the realistic conditions of suppressed water supply and projected build-out of sewer connections.**

## 6.0  DESIGN CRITERIA FOR SEWERAGE SYSTEM AND WASTEWATER TREATMENT PLANTS

### 6.1  Design of Sewers

### 6.1.1  Minimum Size of Sewer

Many sewer blockages in Urban areas occur in the first length of small diameter sewer with less than five house connections. Because of this observation, Nairobi City Council Manual recommends a minimum diameter of 200mm for new sewers. Individual house connections of 150mm diameter is however sufficient.

This is comparable to the recommendations of WHO Report No. 9 of 225mm minimum diameter for Trunk and Branch Sewers and 100mm - 150mm for Property Drains.

To reduce the tendency of blockages, 200mm diameter has been adopted as a minimum sewer size for Kilifi Sewerage System. However, at the upper ends of sewer lines, the expected flows would not achieve self-cleansing velocities except at rather steep sewer gradients. Thus, 150mm diameter sewers should be adopted in the upper lengths of the sewers to alleviate this situation.

### 6.1.2  Hydraulic Design Criteria

The two most commonly used and recommended formulae for hydraulic design of sewers are:

- *Colebrook-White Formula*:  The Darcy Weisbach Formula, combined with the Colebrook White formulation of the friction factor, has long been regarded as the formula that closely relates both pipeline theory and observed pipeline losses. Its main disadvantage is the cumbersome iterative calculations necessary for its solution. However, with the advent of computers and published Design Charts this limitation has been overcome and the formula universally used as the basis for most computer programs used in the design of sewers.

- *Manning Equation:* The Manning equation is widely used because of its simplicity. Although it is empirical, it gives an answer that is within the accuracy required, given the uncertainties associated with the flows generated (population projections, connected population, water consumption per person, etc). The formula is as follows:

$$V = \left( \frac{R^{0.67} \text{ x } S^{0.5}}{n} \right)$$

Where:

| | | |
|---|---|---|
| V | = | velocity of flow, (m/s) |
| n | = | pipe roughness coefficient |
| R | = | hydraulic radius, (m) |
| S | = | slope of the pipeline, (m/m) |

**Table 6.1** below shows the Manning's Pipe roughness coefficients for different pipe materials and diameters.

**Table 6.1: Friction Factor for Manning's Formula**

| Pipe Material | Pipe Dia, mm | Friction Coefficient, n |
|---|---|---|
| Spun Concrete | <= 300, <600 | 0.015 |
| | >= 600 | 0.014 |
| Cast Concrete | All sizes | 0.018 |
| uPVC | All sizes | 0.013 |
| Pitch Fibre | 100 & 150 | 0.014 |

In this study, Manning's Equation has been adopted for the design of gravity sewers. It has been complimented by Design Tables and Charts for the Colebrooke-White Equation, developed by the Hydraulic Research Station in UK.

### 6.1.3   Self-Cleansing Gradients and Velocities

The velocity of flow in a gravity sewer depends on its gradient; the steeper the gradient, the higher the velocity and for the same discharge volume, the shallower the depth of flow in the sewer.

A minimum velocity is required in a sewer to ensure settling of solids do not occur. A velocity of 0.75 m/s is considered as the 'self-cleansing' velocity that will keep solids including silt in suspension. It is important that this velocity is achieved at least once a day. This is ensured by laying sewers at a gradient that will give a velocity of 1.0 m/s at full bore flow. The Nairobi City Council's Adoptive Standards recommends that velocities in sewers should exceed 0.75m/s when flowing full.

Sewer velocity is more important in tropical climates such as in Kilifi Town since it has been noted that at high temperatures, increased biological activity rapidly reduces the dissolved oxygen content of the sewage and can result to build-up of hydrogen sulphide gas. Without oxygen, sulphate reducing bacteria break down the sulphates always present in sewage and hydrogen sulphide gas is produced which turns into sulphuric acid. Hydrogen sulphide gas is known to cause odour and corrosion problems. A velocity of 1.0 m/s is considered necessary in tropical climates, (WHO Sectorial Report No 9) to deal with this problem.

This requirement is more important for trunk mains and is inappropriate for house connections or the secondary sewers for Kilifi Town where flows may be intermittent and retention times short. A minimum velocity of 0.75m/s has been adopted with exception of some critical circumstances where a velocity of 0.6m/s has been allowed.

In areas where ground slopes are flat, the adoption of a minimum velocity of 1.0m/s places a severe constraint on the design of the upper reaches of systems due to the steep gradients required. Thus, flatter gradients have been adopted to decrease the resultant sewer depths and to reduce the number of pumping stations. Regular flushing of sewers should be carried out at the flush manholes to be provided at the upper sewer sections to prevent silting.

The Ministry of Water & Irrigation Practice Manual for Sewerage and Sanitation Services in Kenya (December 2008) on Page 144 explains that the maximum flow velocities were previously specified in order to reduce the possibility of pipe erosion through scouring effects. Such effects were said to occur at flow velocities exceeding 4.0m/s but studies have shown that erosion effects observed at velocities greater than this threshold value are minimal and hence no upper limit of flow velocity is recommended.

The following design parameters have been adopted in the design:

- Minimum velocity at peak flow                                    0.75 m/s
- Minimum velocity in exceptional circumstances        0.6 m/s
- Maximum velocity                                                             3.0 m/s
- Maximum velocity in exceptional circumstances       6.0 m/s

### 6.1.4   Sulphide Generation

Hydrogen sulphide is the main source of corrosion in concrete sewer pipes, particularly with high ambient temperatures and long retention times. Aerobic bacteria on the sewer walls above the sewage level oxidise the hydrogen sulphide gas to sulphuric acid which attacks the concrete wall and result to its rapid deterioration.

The onset of Hydrogen sulphide attack depends upon many variables including;

- Sewage strength and sulphate content
- Dissolved oxygen concentration
- Velocity of flow - at low velocity, anaerobic conditions result through silt and sludge accumulation. Natural oxygen recovery from the atmosphere is also low at low velocities
- Temperature - sewer corrosion is more frequent and intensive in in warm climates as compared to temperate areas

A well-designed and constructed Sewerage System is the best way of preventing occurrence of sulphide attack. It is considered that the relatively short sewer lengths proposed in this project, together with adequate gradients, make the onset of sulphide attack unlikely. HDPE/ uPVC pipes will be used as much as possible in flatter gradients.

In Pumping Mains, sewage retention time less than 30 minutes has been provided to avoid anaerobic conditions and generation of hydrogen sulphide. Injection of air into the main by a compressor is proposed where retention times exceed 30 minutes. Where there is high flow volume with turbulence and splashing, hydrogen sulphide will easily be generated. Proper design of gradient changes in manholes, especially back drop manholes should prevent this.

Flushing of sewers prevents hydrogen sulphide generation because sulphides generation result from slime and sewage deposits.

### 6.1.5    Ventilation of Sewers

Sewers must have adequate ventilation to:
- Remove odorous gases released from the sewage
- Remove explosive and poisonous gases produced in the sewage
- Maintain adequate supply of oxygen in sewers and prevent hydrogen sulphide generation

To ensure adequate ventilation, ventilation columns with extensions should be installed at all house connections, Pumping Stations and Manholes where pumping mains discharge. Manhole covers should also be provided with ventilation slots. Forced ventilation using compressors should be used where necessary.

### 6.1.6    Depth of Sewers

Sewers are designed to flow as much as possible in the direction of the natural ground slope. They should also be laid at depths that permit connection to the existing and future properties within the sewered area. Besides, adequate cover to the sewers ensures protection against damage from live loads transiting on the overburden cover surface.

Nairobi City Council Manual recommends minimum depth of sewers of 1200mm in roads and 900mm in all other areas. Adopting this recommendation at the upstream sewer sections in flat areas leads to unnecessarily deep sewers. However, additional protection can be provided at the upstream section of sewers if shallow depths are adopted which will still result to savings from deep excavations of entire sewer length.

The minimum sewer depths and recommended pipe protection measures in the various circumstances are shown in **Table 6.2** below.

**Table 6.2:  Minimum Sewer Depths and Pipe Protection**

|  | Depth Range | Pipe Protection |
|---|---|---|
| **In Open Spaces** | 0 - 750 mm | Concrete bed & surround or granular bed & surround |
|  | Over 750 mm | Protection governed by factors other than depth |
| **In Roads** | 0 - 1200 mm | Concrete bed & surround |
|  | Over 1200 mm | Protection governed by factors other than depth |

The depth of sewers in Kilifi has been dictated by the constructability of soil conditions given the flat topography, loose sandy soils, depth of the water table and economic considerations.

Standard details for backfilling sewers and its surround have been provided to ensure protection of sewers from unnecessary damages and overburden.

### 6.1.7    Manhole Spacing and Sizes

Manholes permit the inspection and cleaning of sewers and the removal of blockages. They should be provided on sewers at all changes of direction, sewer change of gradient, at every junction, where pipe size changes and generally throughout the sewerage system at intervals sufficiently close to ease sewer cleaning.

Manhole spacing and size based on the sewer diameter have been based on the guidelines in Nairobi City Council Manual as shown in **Table 6.3** below.

**Table 6.3: Guideline to manhole diameter and spacing**

| Sewer Pipe Size (mm) | Manhole Spacing (m) | Manhole Diameter (mm) |
|---|---|---|
| 225 - 375 | 60 | 1050 |
| 450 - 600 | 80 | 1200 |
| 675 – 900 | 100 | 1500 |
| Greater than 900 | 100 | 1500 |

Most sewer blockages occur in the smaller diameter sewers. Thus, for pipe diameters smaller than 225 mm, it is proposed to reduce the manhole spacing to 40m for ease of cleaning and maintenance. The spacing of intermediate manholes in the Kilifi Sewerage System has been guided by the proposed Sewer Layout Plan.

### 6.1.8   Pipe Materials

The choice of pipe material is influenced by:
- Hydraulic and structural design; in consideration of whether it is gravity or forced sewer
- Resistance to chemical and biological processes internally and externally e.g. Corrosion
- Physical properties of the pipe material i.e. strength (to prevent abrasion)
- Types of joints; in view of water tightness which affects infiltration
- Availability of required sewer diameters and necessary fittings including for future replacement
- Cost of materials and installations

Due to the various requirements in the Sewerage System for Kilifi Town, combination of various pipe materials, which are manufactured locally to internationally recognized standards, have been considered. These include;

i.  Pre-cast Concrete Pipes

Spun concrete pipes are manufactured locally by several companies in Kenya. They are the most commonly used for sewer pipes.

Flexible jointed pipes are manufactured in sizes ranging from 150mm to 975mm diameter and are connected using rubber rings. They are vertically cast in vibrated moulds. They are the most commonly used type of concrete pipes.

Rigid jointed pipes are rarely used for sewers. They are connected using tarred hessian and cement mortar. Ogee jointed pipes, commonly used for surface water drainage systems, are available in sizes from 100 mm to 1525 mm diameter.

Concrete pipes are usually laid on a concrete bed and provided with a haunch and surround or reinforcement to meet the loading requirements.

Larger sizes and higher strength classes can be manufactured on order.

The disadvantages of using concrete pipes include their high friction coefficient and susceptibility to corrosion due to the generation of hydrogen sulphide gas especially at high ambient temperatures and long retention time.

ii. uPVC Pipes

Un-plasticised PVC pipes are manufactured in Kenya in metric sizes up to 450 mm diameter. The pipes are manufactured in accordance with KS 06-149 and both rubber ring jointed and cement jointed pipes are available.

Their main advantage is the low costs associated with the purchase, transportation, handling and laying. In addition, most contractors are experienced in handling uPVC pipes. uPVC pipes are resistant to attack from corrosive atmosphere, soils or wastewater conditions.

However, exposure to strong sunlight over a long period can cause brittleness of uPVC sewers, but this has become less common with modern pipes. There has also been reservation regarding the quality of the locally manufactured large diameter uPVC pipes and the ability of Contractors to properly lay these large dimeter pipes. Their use has therefore generally been limited to diameters less than 300 mm. Despite of the high cost, it is customary to specify the use of Class 41 uPVC pipes (with thicker walls) for sewers to provide the additional safeguard.

iii. HDPE Pipes

HDPE pipes are ideal for many different applications including municipal, industrial, energy, geothermal, landfill and more. HDPE pipe is strong, durable, flexible and light weight. When fused together, HDPE has a zero-leak rate because the fusion process creates a monolithic HDPE system. HDPE pipe is also a more environmentally sustainable option as it is non-toxic, corrosion and chemical resistant, has a long design life, and is ideal for trenchless installation methods owing to its flexibility.

With manufacture of HDPE Pipes gaining momentum in the country and considering its rapid use by most Water Service Providers, the benefits of using HDPE pipes in Sewerage Systems including reduction in the number of manholes required, ease of use in confined spaces and resistance to corrosion in the coastal towns, make HDPE Pipes the ideal selection for sewers.

iv. Steel Pipes

Steel pipes are manufactured in Kenya. In the sewerage system, they are used for exposed locations such as river crossings or in pumping mains. However, protection against corrosion is required internally and externally. This is provided using bitumen sheathing with external sheathing reinforced and glass fibre windings. Alternatively, modern proprietary epoxy coatings can be used. Joints are bolted flanges, flexible couplings or spigot and socket joints.

From field investigations, it has been found that when steel pipes are exposed to the strong sunlight, the external protective bitumen coating become brittle and crack, thus become susceptible to the atmosphere. There are also cases where the pipe couplings, and even the pipes, have been vandalised and stolen for recycling purposes. High cost of steel pipes also discourages use in other normal conditions.

All the foregoing four pipe materials have been used in the construction of the existing Sewerage Systems countrywide successfully.

Considering performance, cost and availability, HDPE and concrete pipes are the most appropriate pipes for use in large diameter sewer construction in Kenya. For smaller diameters, uPVC sewer pipes are more cost effective. Steel pipes are to be used for aerial river crossings, pumping mains, high impact resistance and bridging ability, either spun iron or mild steel pipes can be used. The use of locally available standard pipe materials and fittings has been adopted to set the standard within the jurisdiction of KIMAWASCO.

**The Gravity Sewers for Kilifi Town will consist of HDPE/ uPVC pipes and socket & spigot concrete pipes while Pumping Mains will comprise of Steel Pipes. Shallow sewer sections or those laid on road crossings shall consist of flexible jointed concrete pipes protected with reinforced concrete raft slab.**

### 6.1.9   Property Connections

As the designed Sewer Network will comprise Trunk Sewers and Secondary Sewers, only those properties that are adjacent to the sewers will easily / directly connect. Other properties will need to be connected, either by KIMAWASCO's tertiary sewers or by individual plot owners.  It is not feasible at the construction stage to allow for all individual property connections, but, wherever, possible, 160 mm diameter Y-junctions should be provided on the secondary sewers to facilitate connections.

### 6.2     Design of Sewage Pumping Stations

### 6.2.1   Sewage Pumps

The standardization of pumping stations and their equipment is very desirable. It simplifies design, maintenance and repair, and the training of operatives; it also reduces considerably the amount of spare parts which must be kept in store against breakdowns.

Sewage pumps commonly used in Kenya as observed in existing Sewerage Systems in Mombasa and as per the *Final Practice Manual for Sewerage and Sanitation Services in Kenya (MWI, 2008)* are:

      i.   Solids diverters
      ii.  Submersible pump-sets incorporating centrifugal pumps
      iii. Centrifugal pumps
      iv.  Mixed-flow pumps
      v.   Screw Pumps (Sewage 'lift' stations)

Screw Pumps (sewage 'lift' stations) are suitable where the pump station can be located away from human settlements. Wherever electricity is available, it is recommended that pumps be driven by electric motors; elsewhere, diesel engines are considered the better alternative type of prime mover. Renewable energy e.g. Solar or wind power systems can also be used especially for smaller pumps.

Except solids diverters and screw pumps, it is recommended that all sewage and sludge pumps should be protected against blockage by screens; for the smallest pumps, 40 mm clear opening screens are required, but 100 mm openings are suitable for the larger centrifugal and mixed-flow pumps.

### 6.2.2   Sewage Pumping Stations

There are two basic types of sewage pumping stations; sewage lift stations and stations which discharge into pumping mains. In the lift station, sewage is merely raised from a low to a higher level, for subsequent gravity flow.

The design of a pumping station is, to a considerable extent, dictated by the type of pump selected. Thus, a station for a screw pump simply houses the prime movers, and the buildings for ejectors or diverters are essentially partly-buried boxes giving access to the equipment and its control gear.

Roto-dynamic pumps require more sophisticated stations, which can be roughly categorized as either at Wet well or Dry well. Both types of stations normally comprise a substructure below ground level and superstructure, containing special equipment mainly the electrical control panels, which could be damaged by flooding, above the ground surface.

Sewage pumping stations can be broadly classified as follows;

      a)  Submersible Pumping Stations (Wet Well Stations)
      b)  Wet Well / Dry Well Pumping Stations (Dry Well Stations)
      c)  Packaged Pumping Stations

### Wet Well Stations

In such stations, the substructure or wet well contains sewage into which pumps are installed. This arrangement ensures that the pumps are always primed. Usually, the prime movers are located in the superstructure and the drive is via cased shafting in case of vertical-shaft pumps.

In a Wet Well installation, pump maintenance, and especially the removal of blockages, is a constant problem as the pumps usually should be withdrawn to gain access. For this reason, new sewage pumping stations of this type are rarely constructed.

During recent years, several manufactures have started to produce watertight, submersible, portable pumping sets suitable for sewage, each comprising a centrifugal pump set (centrifugal pump and electrical motor). It is preferable to have the compact control equipment above ground level and the remaining unit lowered into underground chamber. This system considerably reduces capital costs and simplifies maintenance as within minutes, a standby unit can replace a faulty set, which can then be transported to a workshop for repair.

It is considered that such installations are suitable for Kenya, when the required pumping capacity lies within the range 450 - 2,500 l/min.

### Dry Well Stations

The substructure of such stations comprises two compartments, a Dry Well to house the pumps and a sewage sump to store the sewage, sludge or effluent to be pumped.

The capital costs of such stations are more expensive than Wet Well stations of similar pumping capacity, but it is considered that the ease of maintenance provided by this arrangement compensates for the differences. It is recommended that all larger sewage pumping stations in Kenya (> 2,500 l/min) should be of this type.

Dry Well sewage pumping stations usually house centrifugal pumps (horizontal or vertical centrifugal pump sets). In general, horizontal centrifugal pumps are cheaper and easier to maintain than vertical pumps. However, vertical pump sets have advantage that the prime mover can be installed above ground level, so that it is protected from flooding caused by heavy rain or a burst on the pipeline. In such installations, the prime mover and pump are connected by shafting with universal joints. It is recommended that, when centrifugal pumps are used, vertical sets be adopted.

Reciprocating sludge pumping sets may also be installed in Dry Well Stations. These small sets, which include the prime mover, are usually located on the floors of the Dry wells to reduce the suction heads on the pump; otherwise the station resembles one housing a centrifugal pump.

### Packaged Pumping Stations

These self-contained, factory-built units are a recent development. They operate by electricity and are fully automated. Usually, a unit is installed underground and comprises pumping sets enclosed in a protected steel substructure. Most are designed as Dry Well stations except that electric motors are usually close-coupled to vertical pumps so that they are also at bottom.

#### 6.2.3   Siting of Sewage Pumping Stations

The sewerage system dictates the approximate locations of all pumping stations. However, the sites for Sewage Pumping Stations should preferably be constructed away from residential property and should always be readily accessible.

Sewage Pumping Stations are mostly sited in low-lying areas, where flooding may be a risk. As a precaution, the floor of superstructure to the Pumping Station should always be elevated above the highest recorded flood level.

Electrical supply and mechanical failures are common occurrence at Sewage Pumping Stations. Thus, all Sewage Pumping Stations should be so located that resulting sewage overflow causes minimum hazard to public health and environment. Where possible, a screened overflow pipe, for use only during emergencies should be provided to convey sewage by gravity to a retention pond or ditch.

### 6.2.4 Capacities of Sewage Pumping Stations Components

**Pumping and Station Capacities**

When a Sewage Pumping Station has roto-dynamic pumps, its total pumping capacity should be compatible with peak flows in the sewerage system it serves; if the sewers are not operating at their design capacities, then the installed pumping capacity should be correspondingly reduced.

It is relatively simple and inexpensive to change or add pumping sets and thereby increase the pumping capacity of a station, if the building is sufficient for future installations. It is reasonable to install pump sets to serve for 5 to 10 years, depending upon the rate of increase of sewage generation in future. Buildings and other ancillary works should have a minimum design life of 20 years.

Sewage Pumping Stations with screw pumps or solids diverters cannot be designed in this way, as once initial installation is complete, the pumping capacities can only be increased by duplicating the installation. Where such types of stations are provided, it is considered reasonable to design them for either the maximum flow the sewerage system served can produce or 50 per cent more than the peak wet weather flows anticipated, whichever is lesser.

If, in the case of solids diverters, this formula results in design flows of 450 l/minute or more, then centrifugal pumps rather than solids diverters should be installed.

**Stand-by Units**

In the smallest sewage pumping stations, the pumping equipment should be duplicated and should be so sized that either one of the two pump sets, working alone, can deal with the peak inflow to the station; that is, there should be 100% standby.

The percentage of standby may be reduced as the number of pump sets installed in a station increases; for example, for a station which should deal with a peak inflow of 1,800 l/min, it may prove cheaper to have three pump sets each rated at 900 l/min rather than two sets each with a capacity of 1,800 l/min; in this case, the provided standby is only 50 %.

It is recommended that the percentage standby never drops below 33 %; that is, the total number of pump sets in larger stations should be such that about three-quarters of pumps can deal with peak flows, with the remaining pump(s) held in stand-by.

**Wet Wells and Sewage Sumps**

The rate of inflow to Sewage Pumping Station normally varies throughout the day. As the installed pump-sets will each have finite capacities rather than variable, a sewage sump providing storage is required to deal with the inflow fluctuations; in the case of Wet Well type of pumping station, the terms "wet well" and "Sewage sump" are synonymous.

Effectively, the capacity of sewage sump is the volume between the highest level at which the pumps start and the lowest level at which they stop. Usually, the highest level will be just below the invert of lowest incoming sewer, to help prevent surcharging of the sewerage system.

A sewage sump's capacity should be related to the rate of inflow and the pump capacities, to reduce wear on the mechanical and electrical equipment in the station by minimizing the number of pump starts. Each pump should be limited to about six starts during any hour; the maximum number of starts occurs when the station inflows is equal to half the pumping capacity of one pump. On the other hand, if sewage sumps are too large, sewage will tend to become anaerobic during its retention.

It is recommended that the capacity of the sewage sump in a Pumping Station be calculated following the formula given below;

**V =300Q**

Where; V is the capacity of the sewage pump in litres
        Q is the maximum rate of sewage inflow during dry weather in litres per second

The capacity of the sewage sump given by the above formulae represent the sum of the capacities of the individual compartments if multiple sumps are provided at a Sewage Pumping Station.

At least two compartment of sewage sump is necessary, to facilitate cleaning of the wells and pipe work and repairs to pumps. These compartments should be interconnected by orifice through the dividing walls which can be closed by penstocks, when necessary, to isolate a compartment.

## 6.3    Design of Wastewater Treatment Plants

### 6.3.1    Selection of the Wastewater Treatment Plant Process / Technology

Wastewater treatment technology has been selected after taking due consideration of the pertinent technical, operational and economic factors, limitations and constraints. In this regard, the technologies have been evaluated based on the following key factors:

**i)    Nature and Strength of Wastewater**

The physical, chemical and biological treatment processes are primarily governed by the nature of pollutants to be removed and their strengths in the wastewater. The treatment technology selected has ensured the attainment of required pollutant removal efficiencies.

**ii)    Cost**

The least cost treatment technology in terms of the both the capital and operation costs has been given preference.

To simplify the evaluation process for the various treatment technologies, the Consultant calculated the dynamic unit cost as average cost/m³ of wastewater treated for different treatment technologies as summarised in **Figure 6.1** below;
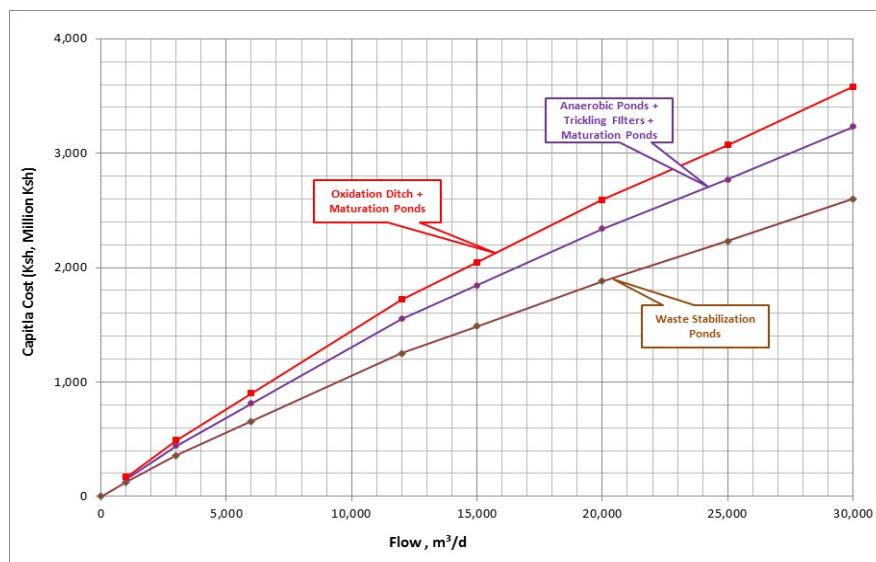


**Figure 6.1: Capital cost for different wastewater treatment technologies**

### iii) Physical Constraints - Land

Land required for installation of treatment plant is the principal physical constraint due to the availability and acquisition cost. Land available at the selected site in consideration of the site topography and terrain for the hydraulics at the WWTP has been assessed for adequacy for the selected treatment technology.

**Figure 6.2** below shows the variation of land requirements for various treatment technologies.
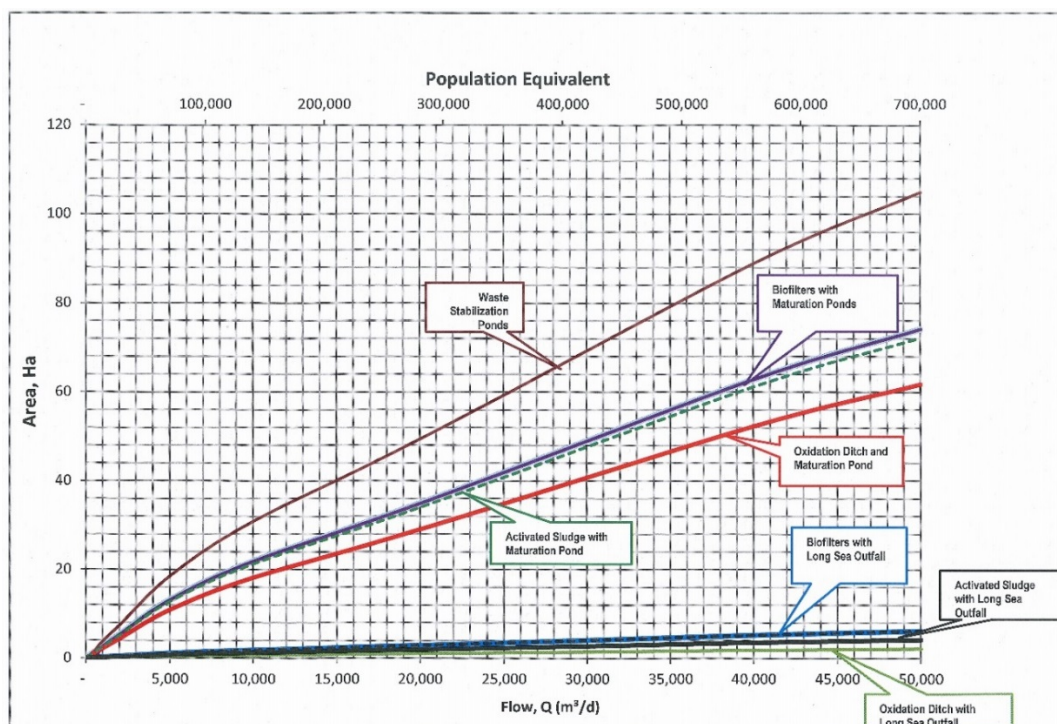


**Figure 6.2: Land Requirement for the Various Treatment Technologies**

### iv) Operational Skills

Treatment technologies whose skill requirement for operation and maintenance can be obtained locally, with minimum training of operators, has also been given preference.

### v) Sludge Production

Different technologies generate varied amounts of sludge during wastewater treatment process. The amount of sludge generated and its disposal or reuse has a huge impact on the capital cost, operational cost and land requirement. The selection of wastewater treatment technology has considered minimal production of sludge and its safe disposal.

### vi) Energy Recovery

Methane gas is usually generated during wastewater treatment processes. Some wastewater treatment technologies such as the Activated Sludge have a dominant anaerobic digestion processes involving sludge which produces substantial amounts of methane. Energy production can also be achieved through direct incineration of sludge.

It is ideal to collect and utilize the produced methane gas for the generation of power and thereby reduce the cost of energy at the WWTP. However, this is only economically and financially viable for treatment technologies with high calorific value in sludge and methane gas.

### vii) Fertilizer Recovery

The presence of nutrients such as nitrogen, phosphorous and potassium makes sludge a valuable fertilizer resource after stabilization. Natural and mechanical composting can be practised for conversion of sludge into fertilizer.

### viii) Sludge Handling

In the absence of energy and fertilizer recovery, generated sludge (mostly liquid) must be disposed of in a safe and sound manner to the public and environment at the Sludge Dump Site. Dewatering of sludge by use of Sludge thickeners, Sludge Drying Beds, etc. prior to transportation is necessary. Some of these techniques are labour and land intensive and involve mechanical equipment.

### ix) Sludge / Solid Waste Dump Site

After dewatering, solid sludge is easily transported to the Sludge Dump Site for final disposal. The sludge may also be combined with grits and screenings from the Plant for dumping. The Sludge Dump site shall preferably be developed near the Waste Water Treatment Plant site to reduce the hauling distance and to minimize cost of transportation. The dumped sludge is compacted with bulldozer and covered with a thick layer of clean soil to minimize nuisance through odour and flies.

Site evaluation and selection of the Sludge Dump Site have been carried out based on following key factors:

- Topography of the land and its potentials for erosion and runoff
- Soil Characteristics
- Soil depth to ground water
- Accessibility & proximity to critical areas

Availability of clean earth for covering the dumped sludge / solid waste have been considered to minimize hauling distance and transportation cost.

### x) Mechanical Equipment

The selected system shall be such that minimum mechanical equipment needs to be provided. Unnecessary mechanical equipment has been avoided. The system has been designed such that maximum of the mechanical equipment is of local make.

### xi) Nuisance

The degree of colour, odour and noise shall be below the nuisance thresh-hold, especially, regarding the proximity of the Waste Water Treatment Plant to the built-up areas.

## 6.3.2   Alternative Wastewater Treatment Plant Process / Technology

The following biological Wastewater Treatment Technologies have been analysed in detail using the above criteria (*Sub-section 6.3.1*):

### i)   Waste Stabilization Ponds



| Application Level: | Management Level: | Inputs: ■ Blackwater ■ Brownwater |
| --- | --- | --- |
| ☐ Household | ☐ Household | ■ Greywater ( ■ Sludge) |
| ☒ Neighbourhood | ☒ Shared | **Outputs:** ■ Effluent ■ Sludge |
| ☒☒ City | ☒☒ Public | |

Waste Stabilization Ponds (WSPs) are large basins enclosed by earth embankments in which raw wastewater is treated by entirely natural processes involving algae and bacteria. Since these processes are unaided, the rate of oxidation is slower, and thus

hydraulic retention times are longer than in conventional wastewater treatment. WSPs are the preferred method of wastewater treatment in developing countries where sufficient land is normally available and where the temperature is most favourable for their operation.

There are three principal types of WSP: anaerobic, facultative and maturation ponds which are linked in series. Anaerobic ponds and facultative ponds are designed for BOD (biochemical oxygen demand) removal and maturation ponds are designed for faecal bacterial removal. Some removal of faecal bacteria (especially of *Vibrio cholerae*) occurs in anaerobic and facultative ponds, which are also responsible for most of the removal of helminth eggs; and some removal of BOD occurs in maturation ponds, which also remove some of the nutrients (N and P).

A typical layout of Waste Stabilization Pond is given in **Figure 6.3** below;
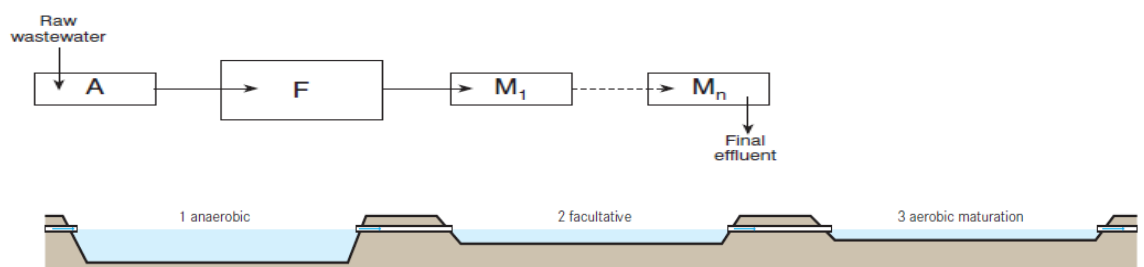


**Figure 6.3: Layout of Waste Stabilization Ponds**

The advantages of WSP are that they are simple, low-cost, highly efficient and robust. The disadvantages of WSP include high land requirements and odour release.

ii)  **Trickling Filters / Biofilter**

| Application Level: | Management Level: | Inputs: 🟦 Effluent 🟫 Blackwater |
|---|---|---|
| ⬜ Household | ⬜ Household | 🟧 Brownwater ⬜ Greywater |
| ⊞ Neighbourhood | ⬜ Shared | |
| ⊞⊞ City | ⊞⊞ Public | Outputs: 🟦 Effluent 🟫 Sludge |

A trickling filter is a fixed-bed, biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter using sprinkler as shown in **Figure 6.4** below.
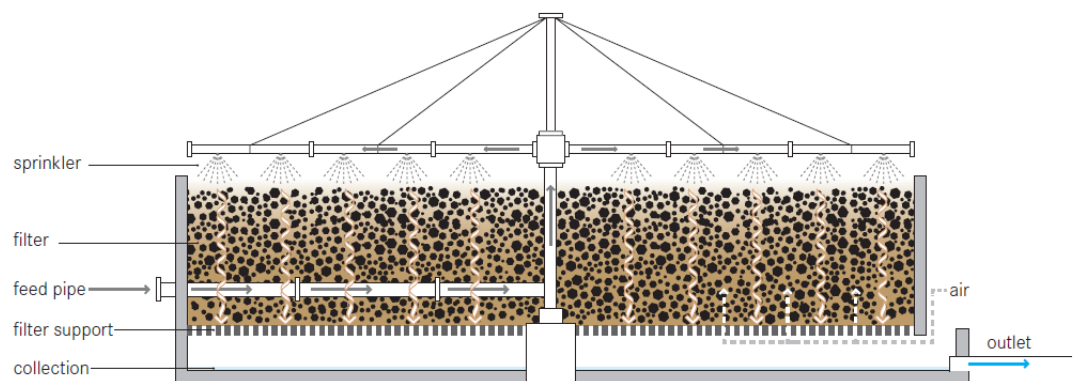


**Figure 6.4: Sectional View of a Circular Biofilter**

As the water migrates through the pores of the filter, organics are degraded by the biofilm covering the filter material. They produce high quality effluents (e.g. <20 mg BOD/l and <30 mg SS/l) without requiring large areas of land or consuming vast quantities of electricity. In many situations in developing countries they are much more appropriate than activated sludge. Trickling Filters comprise a 2-3 m deep bed of 50-100 mm rock.

The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles, or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water, while generating new biomass.

The advantages of trickling filters are;
- High quality effluents without requiring large areas of land or consuming much electricity
- Efficient nitrification
- Operation at a range of organic and hydraulic loading rates

The disadvantages include;
- High capital costs
- Skilled personnel for operation and maintenance
- Constant source of electricity and wastewater flow
- Problems associated with flies and odour

### iii) Oxidation Ditch / Extended Aeration

| **Application Level:** | **Management Level:** | **Inputs:** ▭ Effluent ▭ Blackwater ▭ Brownwater ▭ Greywater |
|---|---|---|
| ▭ Household | ▭ Household | |
| [*] Neighbourhood | ▭ Shared | **Outputs:** ▭ Effluent ▭ Sludge |
| [**] City | [**] Public | |

Oxidation ditches are a direct modification of conventional activated sludge. Their essential operational features are that they receive raw wastewater (after preliminary treatment) and provide longer retention times: the hydraulic retention time is commonly 0.5–1.5 days and that for the solids 20–30 days. The latter, achieved by recycling >95 per cent of the activated sludge, ensures minimal excess sludge production and a high degree of mineralization in the small amount of excess sludge that is produced. Sludge handling and treatment is almost negligible since the small amounts of waste sludge can be readily dewatered without odour on drying beds. The other major difference is in reactor shape: the oxidation ditch is a long continuous channel, usually oval in plan and 2–3 m deep.

The ditch liquor is aerated by several aerators, which impart a velocity to the ditch contents of 0.3–0.4 m/s to keep the activated sludge in suspension. The ditch effluent is discharged into a secondary sedimentation tank to permit solids separation and sludge return and to produce a settled effluent with low BOD and SS. Removals consistently >95 per cent are obtained for both BOD and SS.

Currently, there are few oxidation ditches in developing countries since Waste Stabilization Ponds are usually more favourable, both in terms of costs and faecal bacterial removal; although where there is a reliable electricity supply but insufficient land for ponds Oxidation Ditches are increasingly being used.

The advantages of Oxidation ditches include;
- Resistance to organic and hydraulic shock loads
- High reduction of BOD and pathogens (up to 99%)
- High nutrient removal possible

The limitations / disadvantages of using oxidation ditches include;
- High energy consumption
- Constant supply of energy
- High capital and operating costs
- Require operation and maintenance by skilled personnel

### iv) Sequencing Batch Reactor (SBR)

| Application Level: | Management Level: | Inputs: Effluent   Blackwater |
|---|---|---|
| Household | Household | Brownwater   Greywater |
| Neighbourhood | Shared | Outputs: Effluent   Sludge |
| City | Public | |

The Sequencing Batch Reactor (SBR) is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. The major difference between SBR and conventional continuous-flow activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems thus smaller  footprint (see **Figure 6.5** below).
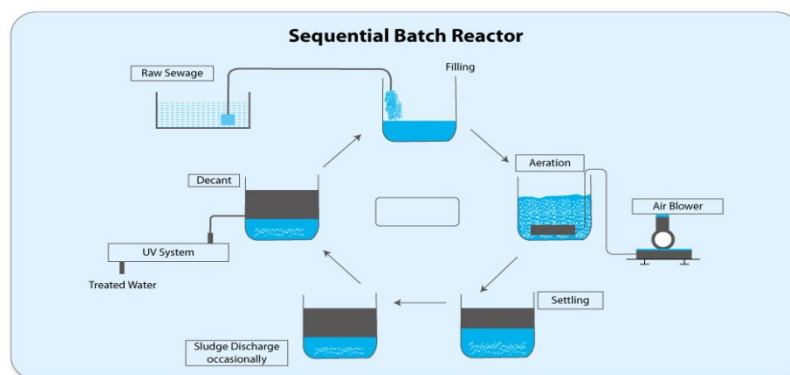


**Figure 6.5: Schematic Showing SBR operational cycle**

There is a degree of flexibility associated with working in a time rather than in a space sequence. The duration, oxygen concentration, and mixing in these periods could be altered per the needs of the Treatment Plant.

SBRs require controls to reduce energy consumption and enhance the selective pressures for BOD, nutrient removal, and control of filaments. This range from a simplified float and timer based system to a more complex PC based systems. An appropriately designed SBR process is a unique combination of equipment and software. Working with automated control reduces the number of operator skill and attention requirement.

SBRs does not include primary settling tanks; screening of solids and oil / grease removal should be accomplished prior to the activated-sludge process. Flow equalization is also critical where significant variations in flow rates and organic mass loadings are expected. A plant utilizing an influent equalization basin will be able to have a true batch reaction.

### v) Sub-marine Outfall

This is a submarine pipeline or tunnel that discharges wastewater under the sea surface. In the case of municipal wastewater, effluent is often being discharged after having undergone no or only primary treatment, with the intention of using the assimilative capacity of the sea for further treatment.

The main advantages of marine outfalls for the discharge of wastewater include:
- Natural dilution and dispersion of organic matter, pathogens and other pollutant,
- Ability to keep the sewage field submerged due to deep discharge points
- Greater die-off rate of pathogens due to the greater distance they should travel to shore
- Less expensive than advanced Wastewater Treatment Plants i.e. not energy-intensive

For effective operation of outfall and its diffusers, preliminary treatment of wastewater is important. The combined capital and operation cost of preliminary treatment is about one tenth that of conventional biological treatment and require much less land.

**However, sub-marine outfalls for partially treated or untreated wastewater remain controversial. The design calculation and computer models for pollution modelling have been criticized, arguing that dilution has been overemphasized and that other mechanisms work in the opposite direction, such as bioaccumulation of toxins, sedimentation of sludge particles and agglomeration of sewage particles with grease.**

Outfall materials include polyethylene, stainless steel, carbon steel, glass-reinforced plastic, reinforced concrete, cast iron or tunnels through rock. Common installation methods for pipelines are float and sink, bottom pull and top pull.

For final polishing of treated effluent (pathogen reduction) before disposal into the environment, the following processes have been considered to formulate Wastewater Treatment Trains:
- Maturation Ponds
- Chlorination
- Sea outfall

## Preliminary Treatment

Regardless of the Wastewater Treatment technology considered, it is important to have a preceding preliminary Treatment Process at the Waste Water Treatment Plant.

Wastewater contains large solids and grit that can interfere with treatment processes through accumulation of solids, frequent blockages, abrasion of mechanical parts and increased maintenance on wastewater treatment equipment. To minimize potential problems and extend the life of sanitation infrastructure, these materials require separate handling. Preliminary treatment removes these constituents from the influent wastewater.

Some of the preliminary treatment processes are briefly described below;

### a) Screening

Screening is the first unit operation used at Wastewater Treatment Plants (WWTPs). It removes coarse objects such as rags, paper, plastics, and metals to prevent damage and clogging of downstream equipment, piping, and appurtenances. These screens can be cleaned either manually or mechanically.

Manually cleaned screens require little or no equipment maintenance and are suitable for small WWTPs with few screenings. However, they require frequent raking to avoid clogging and high backwater levels that cause build-up of solids matter on the screen. The increased raking frequency increases labour costs.

Mechanically cleaned screening systems are popular in modern WWTPs because they reduce labour costs and improve flow conditions resulting from screen capture. However, they have a high equipment maintenance costs. A screening compactor is usually situated close to the mechanically cleaned screen and compacted screenings are

conveyed to a dumpster or disposal area. Plants utilizing mechanically cleaned screens should have a standby screen to put in operation when the primary screening device is out of service.

Coarse screens and fine screens are available for use at the WWTPs. Coarse screens remove large solids, rags, and debris from wastewater, and typically have openings of 6mm or larger. Fine screens are used to remove materials that may create operation and maintenance problems in downstream processes, particularly in systems that lack primary treatment. Typical opening sizes for fine screens are 1.5 to 6 mm.

b)  **Grit Removal**

Grit includes sand, gravel, cinder or other heavy solid materials that have higher specific gravities than the organic biodegradable solids in the wastewater. Removal of grit prevents unnecessary abrasion and wear of mechanical equipment, grit deposition in pipelines and channels and accumulation of grit in anaerobic digesters and aeration basins. Removal of grit is carried out in a channel or chamber, where the velocity of the incoming wastewater is adjusted to allow settlement of sand and grit. Grit removal facilities typically precede primary clarification, and follow screening to prevent large solids from interfering with grit handling equipment. In secondary treatment plants without primary clarification, grit removal should precede aeration (Metcalf & Eddy, 1991).

Many types of grit removal systems exist, including;
- Aerated grit chambers
- Vortex-type (paddle or jet induced vortex) grit removal systems
- Detritus tanks (short-term sedimentation basins)
- Horizontal flow grit chambers (velocity-controlled channel)
- Hydrocyclones (cyclonic inertial separation)

Various factors must be taken into consideration when selecting a grit removal process, including the quantity and characteristics of grit, potential adverse effects on downstream processes, head loss requirements, space requirements, removal efficiency, organic content and cost.

c)  **Flow Control and Overflow**
Flow control requires that a flow control device be incorporated at the inlet works to restrict the forward flow to treatment i.e. to avoid hydraulic overloading of the subsequent treatment units.

A summary of the descriptive comparison of the above wastewater treatment technologies / processes is given in **Table 6.4** on **Page 6-17**.

## Table 6.4: Descriptive Comparison of Wastewater Treatment Technologies / Processes

| Treatment Process | Standard of Treatment | Process Reliability | Process Complexity | Operation & Maintenance Requirements | Land Requirements | Civil Construction Requirements | M & E Equipment | Sludge Production | Environmental Considerations |
|---|---|---|---|---|---|---|---|---|---|
| **Waste Stabilisation Ponds** | Good, except for nutrient removal | Very good, but climate dependent | Extremely simple. No skills needed | Very limited and simple | Large areas of land needed. | Very simple | Almost none, except, possibly, at the inlet works | Limited sludge production. Sludge is stable and requires no further treatment | High environmental acceptance. |
| **Aerated Lagoons** | Good, except for nutrient and bacterial removal. | Good, but partly subject to power outages and mechanical failure | Very simple. No skills needed. | Limited and straightforward | High land requirements, but not as large as WSPs | Very simple | Apart from the inlet works, only the surface aerators | Limited sludge production. Sludge is stable and requires no further treatment | Moderate environmental acceptance. |
| **Biological Filters** | Very good, except for nutrient and bacterial removal. | Good, but subject to power outages and mechanical failure | Simple. Limited skills required. | Moderate, but straightforward | Moderate land requirements | Complicated RC structural requirements. | Moderate degree of M&E plant needed. | Sludge from primary & secondary settlement needs treatment | Some aspects need further environmental consideration. |
| **Activated Sludge** | Very good, except for nutrient and bacterial removal. | Good, but subject to power outages and mechanical failure | Complex. Highly skilled manpower needed | High requirement for O&M and skilled staff | Minimum land requirements. | Very complicated RC structural requirements. | High input of M&E equipment needed | Sludge from primary & secondary settlement needs treatment | Many aspects need further environmental consideration. |
| **Oxidation Ditch** | Very good, except for nutrient and bacterial removal. | Good, but subject to power outages and mechanical failure | Simple. Limited skills required. | Moderate requirement for skilled O&M staff | Moderate land requirements. | Moderate construction requirements. | Moderate degree of M&E plant needed. | Limited sludge production. Sludge is stable and requires no further treatment | Some aspects need further environmental consideration. |

**Notes:**

1. All treatment processes except waste stabilisation ponds will require additional treatment, such as sand filtration and disinfection or maturation ponds, to achieve bacteriological reduction.
2. All the treatment processes considered will require additional process units to achieve nutrient removal.
3. The activated sludge process and the oxidation ditch most easily lend themselves to nutrient reduction using the Modified Activated Sludge (MAS) process.

### 6.3.3  Identification of Site for the Wastewater Treatment Plant (WWTP)

The location of the proposed Wastewater Treatment Plant(s) is identified after the selection of wastewater treatment technology and determination of the land required for the installation of the various units of the WWTP. Possibilities of future extension of the WWTP is also considered.

The factors that have been considered to select appropriate location of the WWTP are:

#### 6.3.3.1  Land-Use

In the Land-use Map, different areas of Kilifi Town have been assigned varied existing and proposed uses. Areas earmarked for residential, industries, agriculture, forests and social amenities are considered less suitable for the location of a Wastewater Treatment Plant (WWTP). On the other hand, public utility or undeveloped Agricultural Land located away from the sensitive residential areas are preferred.

#### 6.3.3.2  Distance of Effluent Discharge Point

The distance from the WWTP site to the final receiving environment such as the river and ocean, is an important consideration in site selection. Preference is given to the sites that require shorter lengths of Outfall Sewers.

#### 6.3.3.3  Topography of the Sewered Area

An ideal WWTP site should be located on a low-lying area of the sewerage system for gravity conveyance. Otherwise, pumping stations become necessary thereby increasing both capital cost and the operation and maintenance requirements of the sewerage system.

#### 6.3.3.4  Topography of Site

The slope at an ideal site should permit the gravity flow within the WWTP without requiring excessive excavations for the structures. Slopes less than 1:20 are preferred.

#### 6.3.3.5  Geological Conditions

A site with low water table and whose soils are impermeable is considered ideal with respect to geological considerations. For instance, silt or clay soils are suitable for pond construction.

More often, the geological formation within a Town is fairly similar. For instance, all the candidate sites in Kilifi Town comprise of a mixture of well drained, deep, dark red to reddish brown, friable, sandy clay loam to sandy clay, with top soil of loamy sand and well drained, very deep, yellowish red, very friable, fine sandy loam to fine sandy clay loam. These soils are suitable for WWTP (Waste Stabilization Ponds) construction.

#### 6.3.3.6  Existing Infrastructure

Proximity to infrastructural systems such as roads, electricity and portable water is sought for while siting for a WWTP location. It reduces cost of construction and operation & maintenance requirements of the WWTP. Sites that are closer to existing infrastructure are preferred.

#### 6.3.3.7  Potential for reuse of treated wastewater

Treated wastewater can be reused for beneficial purposes such as agricultural irrigation, industrial processes, ground water recharge, etc. Proximity to the potential re-use application and relative elevation difference (for gravity conveyance) is preferred in siting of WWTP. For instance, downstream arable land would make a WWTP site ideal for agricultural irrigation.

#### 6.3.3.8  Land Acquisition

In this criterion, preference is given to sites owned by government agencies such as Ministries, County Governments, etc. This ensures that the project affected persons are kept to a minimal and reduces the cost of resettlement and compensation.

## 7.0   FORMULATION OF ALTERNATIVE DEVELOPMENT STRATEGIES

### 7.1   Justification of Study Area

It was proposed in the World Health Organisation (WHO) Report No. 9 that by the year 2000 all urban areas that have a population density greater than 124 persons per hectare should be connected to sewerage systems. This proposal aims to outline the extent to which the sewerage projects should be prioritized in the developing nations. The population pattern in Kilifi Town is distributed and dense settlement exists in dispersed areas. The effect of the sparse settlement on the overall population density in Kilifi Town is reductive.

The present population density (year 2016) for the entire study area is approximately 13 persons per hectare while the projected year 2040 population density is 37 persons per hectare. The highest projected population density in year 2040 is expected in Sokoni sub-location at approximatively 106 persons per hectare. These population densities are below the guidelines of the WHO Report No. 9 but have been adopted for the design of Sanitation System for Kilifi Town.

### 7.2   Delineation of Drainage Areas

The Sewerage System for Kilifi Town has been developed based on drainage areas. A drainage area refers to a natural boundary within which the topography permits convergence of surface water flow to a single point at a lower elevation.

A total of seventeen (17) drainage areas have been formulated in Kilifi Town.

Based on the projected land use, projected population and water demand as detailed in the previous Chapters (including suppressed conditions), the sewage generated (Dry Weather Flow) in the various design horizons per Drainage Area including $BOD_5$ is summarised in **Table 7.1** below.

**Table 7.1: Summary of Sewage and $BOD_5$ Generated per Drainage Area**

| Drainage Area | Coverage (Ha) | Year 2025 | | Year 2040 | |
|---|---|---|---|---|---|
| | | DWF (m³/d) | $BoD_5$ (mg/l) | DWF (m³/d) | $BoD_5$ (mg/l) |
| 1 | 169 | 283 | 523 | 1,041 | 535 |
| 2 | 134 | 512 | 541 | 1,993 | 545 |
| 3 | 195 | 309 | 535 | 1071 | 544 |
| 4 | 100 | 76 | 661 | 186 | 669 |
| 5 | 140 | 79 | 509 | 174 | 537 |
| 6 | 123 | 70 | 504 | 156 | 534 |
| 7 | 55 | 42 | 585 | 101 | 601 |
| 8 | 100 | 64 | 502 | 154 | 530 |
| 9 | 165 | 169 | 521 | 523 | 537 |
| 10 | 509 | 659 | 494 | 2647 | 507 |
| 11 | 144 | 102 | 454 | 306 | 484 |
| 12 | 241 | 149 | 440 | 431 | 476 |
| 13 | 637 | 335 | 421 | 903 | 465 |
| 14 | 425 | 403 | 480 | 1478 | 499 |
| 15 | 148 | 82 | 417 | 203 | 462 |
| 16 | 282 | 139 | 399 | 337 | 450 |
| 17 | 246 | 124 | 405 | 303 | 454 |
| **Mean** | - | - | 492 | - | 515 |
| **Total** | 2,148 | 3,595 | - | 12,007 | - |

The Projected Dry Weather Flow for the study area of Kilifi Town at the Design Horizon (Year 2040) is approximately **12,000 m³/day**.

A layout Plan showing these drainage areas is given in **Figure 7.1** on **Page 7-2.**

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
Waste Water Master Plan for Mombasa and Selected Towns within the Coast Region

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KILIFI TOWN
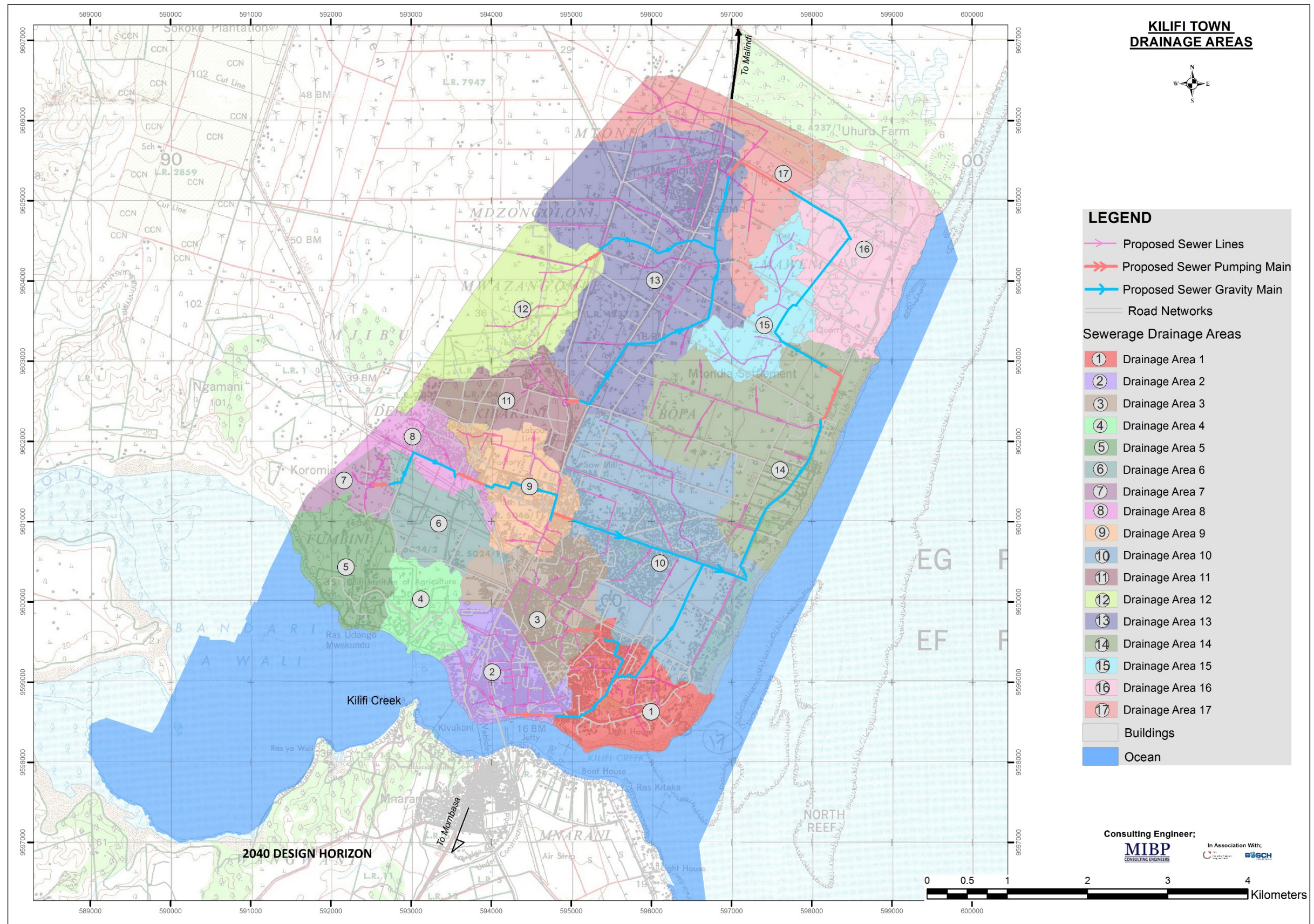
Figure 7.1: Proposed Drainage Areas

**7.3**     **Description of Alternative Wastewater Management Schemes**

Three Alternative Wastewater Management Schemes have been formulated and evaluated to serve the sanitation needs of Kilifi Town up to Year 2040 as briefly described below;

### i. Alternative 1 – Centralised Wastewater Treatment Plant at a dis-used quarry at Uhuru Farm (Bofa/Maweni area)

This alternative involves treating wastewater generated in Kilifi Town to a centralized Waste Water Treatment Plant (ultimate design capacity - 12,000 m³/day) located at a dis-used quarry near Uhuru Farm. This site has been selected after an evaluation based on a check-list of pertinent considerations of physical, environmental and economic factors including the ease with which wastewater generated from Kilifi Town can be conveyed by minimal pumping to the site, land availability at the dis-used quarry , its safe distance from the built-up areas and proximity to a water body for discharge of effluent.

Due to the nature of topography in Kilifi, the wastewater will be conveyed to the proposed centralized Wastewater Treatment Plant via a series of gravity and pumping sewers.  The 11 Nr Pumping Stations have been positioned at strategic locations to ensure least pumping heads and shortest rising mains, while serving the entire drainage area.

A full conventional Wastewater Treatment Plant, comprising of Waste Stabilization Ponds has been adopted considering availability of land, costs of land acquisition, capital costs and low operation and maintenance requirements. The main components of the Wastewater Treatment Plant are as follows:

- Inlet Works
- Waste Stabilization Ponds - Anaerobic, Facultative and Maturation Ponds
- Sludge Drying Beds
- Staff Houses and Administration Buildings
- Site and Ancillary Works

A summary of the Sewerage Pumping Components and Treatment Technology for **Alternative 1** is given in **Table 7.2** below.

**Table 7.2: Alternative Scheme 1 - Pumping Components and Treatment Technology**

| Rising mains | | Pumping Stations | | | | Wastewater Treatment Plant |
|---|---|---|---|---|---|---|
| Length (m) | Dia. (mm) | Pumping Station Ref. | Design flow (m³/h) | Pumping Head (m) | Power (kW) | Treatment Plant |
| 840 | 500 | P1 | 712 | 21 | 57 | Waste Stabilization Ponds, Capacity 12,000 m³/day |
| - | - | P2 | 593 | 5 | 10 | |
| - | - | P3 | 352 | 5 | 6 | |
| 680 | 250 | P4 | 184 | 16 | 12 | |
| 585 | 150 | P5 | 85 | 27 | 9 | |
| 345 | 150 | P6 | 54 | 13 | 3 | Area Required 30Ha |
| 236 | 100 | P7 | 33 | 17 | 2 | |
| 160 | 100 | P8 | 23 | 14 | 1 | |
| 960 | 200 | P9 | 128 | 15 | 8 | |
| 402 | 100 | P10 | 24 | 19 | 2 | |
| 202 | 100 | P11 | 24 | 12 | 1 | |

A detailed Layout Plan for Alternative Scheme 1 is given in   **Figure 7.2** on **Page 7-4.**

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
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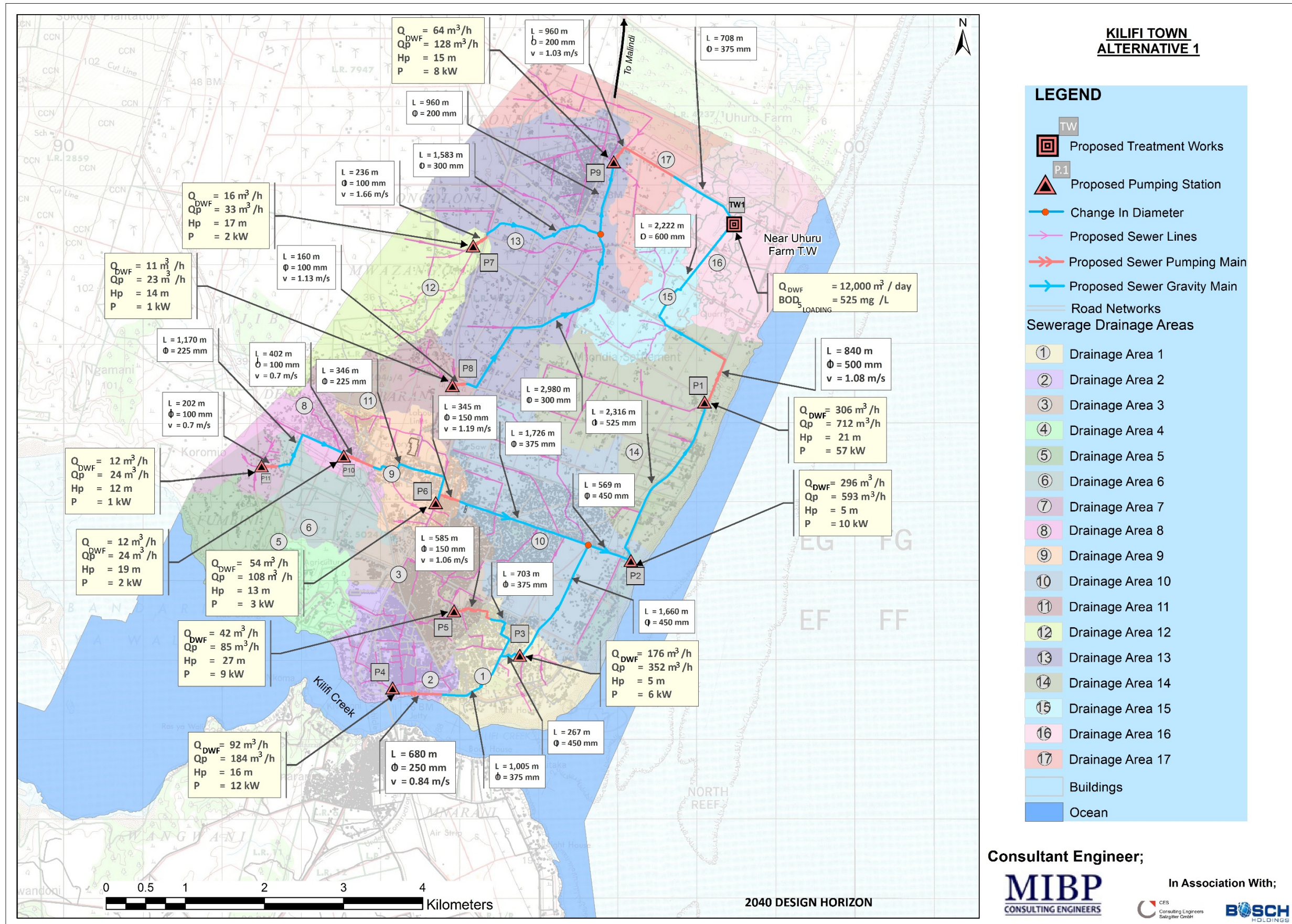
**Figure 7.2: Alternative Scheme 1**

ii.  **Alternative 2 – 2 Nr De-centralised Wastewater Treatment Plants, 1 Nr at a dis-used quarry at Uhuru Farm and 1 Nr at Baobab (Hospital/Nayeni area) near Kilifi Town**

This alternative involves a decentralized wastewater management scheme to reduce conveyance distances. Two (2) Wastewater Treatment Plants are proposed, one is located at a dis-used quarry near Uhuru Farm (TW 1 - Ultimate design capacity 2,000 m$^3$/day) and the other at Baobab area (Hospital/Nayeni area) near Kilifi Town (TW 2 - Ultimate design capacity 10,000m$^3$/day).

Due to the nature of topography in Kilifi Town, the wastewater will be conveyed to the 2Nr. proposed Wastewater Treatment Plants via series of gravity and pumping mains. The 10Nr. proposed Pumping Stations will be located at strategic points of the Sewerage System with least pumping heads and shortest rising mains.

A full conventional Wastewater Treatment Plant, comprising of Waste Stabilization Ponds has been adopted considering availability of land, costs of land acquisition, capital costs and low operation and maintenance requirements. The main components of the Wastewater Treatment Plant include:

- Inlet Works
- Waste Stabilization Ponds - Anaerobic, Facultative and Maturation Ponds
- Sludge Drying Beds
- Staff Houses and Administration Buildings
- Site and Ancillary Works

A summary of the Sewerage Pumping Components and Treatment Technology in **Alternative 2** is given in **Table 7.3** below.

**Table 7.3: Alternative Scheme 2 - Pumping Components and Treatment Technology**

| Rising mains | | Pumping Stations | | | | Wastewater Treatment Plants | |
|---|---|---|---|---|---|---|---|
| Length (m) | Dia. (mm) | Pumping Station Ref. | Design flow (m$^3$/h) | Pumping Head (m) | Power (kW) | TW1 | TW2 |
| 680 | 250 | P1 | 184 | 16 | 12 | Waste Stabilization Ponds at Uhuru Farm, Capacity 2,000m$^3$/d | Waste Stabilization Ponds at Baobab (Hospital/ Nayeni area), Capacity 10,000m$^3$/d |
| - | - | P2 | 352 | 5 | 6 | | |
| 585 | 150 | P3 | 85 | 27 | 9 | | |
| 202 | 100 | P4 | 24 | 12 | 1 | | |
| 402 | 100 | P5 | 24 | 19 | 2 | | |
| 345 | 150 | P6 | 108 | 13 | 3 | | |
| 160 | 100 | P7 | 23 | 14 | 1 | Area Required 5Ha | Area Required 24Ha |
| 236 | 100 | P8 | 33 | 17 | 2 | | |
| 960 | 200 | P9 | 128 | 15 | 8 | | |
| 840 | 200 | P10 | 120 | 19 | 9 | | |

A detailed Layout Plan for Alternative Scheme 2 is given in **Figure 7.3** on **page 7-6.**

Water and Sanitation Service Improvement Project – Additional Financing (WaSSIP - AF)
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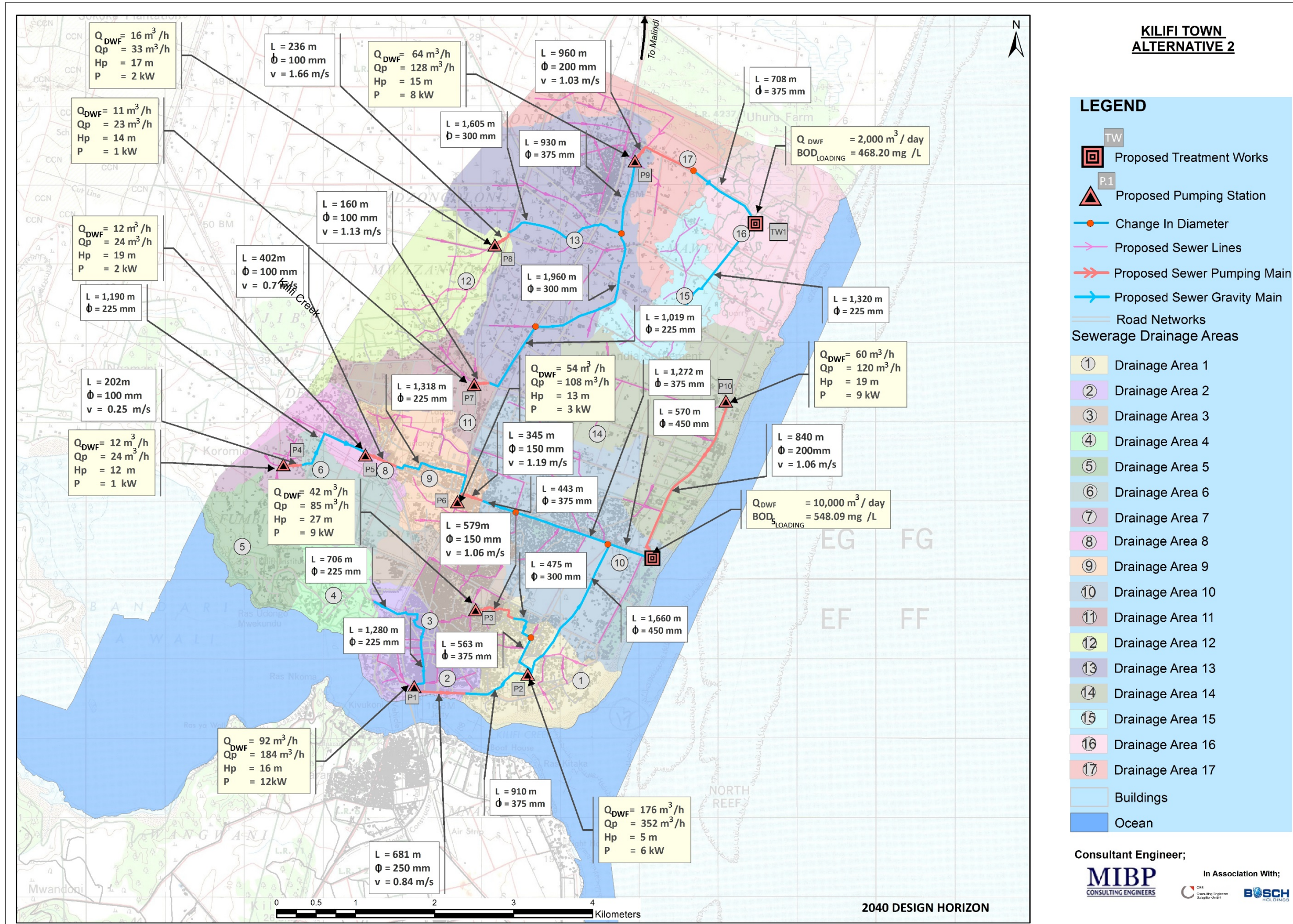
Figure 7.3: Alternative Scheme 2

### iii. Alternative 3 – Centralized Scheme with Preliminary Treatment and a Long Sea Outfall at Uhuru Farm

This Alternative Scheme entails conveying wastewater generated in Kilifi Town to a centralized location at Uhuru Farm for preliminary treatment before discharge by a 3.1 Km of Long Sea Outfall as the adopted treatment technology.

As in alternative 1, this site has been selected after evaluation of pertinent physical, environmental and economic considerations including the ease with which wastewater generated from Kilifi Town can be conveyed by minimal pumping to the site land availability at the dis-used quarry, its safe distance from the built-up areas and proximity to the Indian Ocean for discharge of effluent.

Due to the nature of topography in Kilifi Town, the wastewater will be conveyed to the proposed site via a series of gravity and limited pumping system comprising of 11 Nr Pumping Stations. An additional Booster Pumping Station is required after the Preliminary Treatment for the discharge of wastewater through Long Sea Outfall.The Preliminary Treatment will entail screening and grit removal, screening and grit removal only.

The main components of the Wastewater Treatment Plant include:

- Preliminary Treatment / Inlet Works
- Long Sea Outfall - 3.1 Km long
- Surge Chamber and Booster Pumping Station
- Staff Houses and Administration Buildings
- Site and Ancillary Works

A summary of the Sewerage Pumping Components and Treatment Technology for **Alternative 3** is given in **Table 7.4** below.

**Table 7.4: Alternative Scheme 3 - Pumping Components and Treatment Technology**

| Rising mains | | Pumping Stations | | | | Wastewater Treatment Plant |
|---|---|---|---|---|---|---|
| Length (m) | Dia. (mm) | Pumping Station Ref. | Design flow ($m^3$/h) | Pumping Head (m) | Power (kW) | Treatment Plant |
| 840 | 500 | P1 | 712 | 21 | 57 | Preliminary Treatment + Long Sea Outfall Capacity 12,000 $m^3$/day  Area Required 1Ha |
| - | - | P2 | 593 | 5 | 10 | |
| - | - | P3 | 352 | 6 | 4 | |
| 680 | 250 | P4 | 184 | 16 | 12 | |
| 585 | 150 | P5 | 85 | 27 | 9 | |
| 345 | 150 | P6 | 54 | 13 | 3 | |
| 236 | 100 | P7 | 33 | 17 | 2 | |
| 160 | 100 | P8 | 23 | 14 | 1 | |
| 960 | 200 | P9 | 128 | 15 | 8 | |
| 402 | 100 | P10 | 24 | 19 | 2 | |
| 202 | 100 | P11 | 24 | 12 | 1 | |
| 3,100 | 400 | P12 | 1,000 | 20 | 30 | |

A detailed Layout Plan for Alternative Scheme 3 is given in **Figure 7.4** on **Page 7-8**
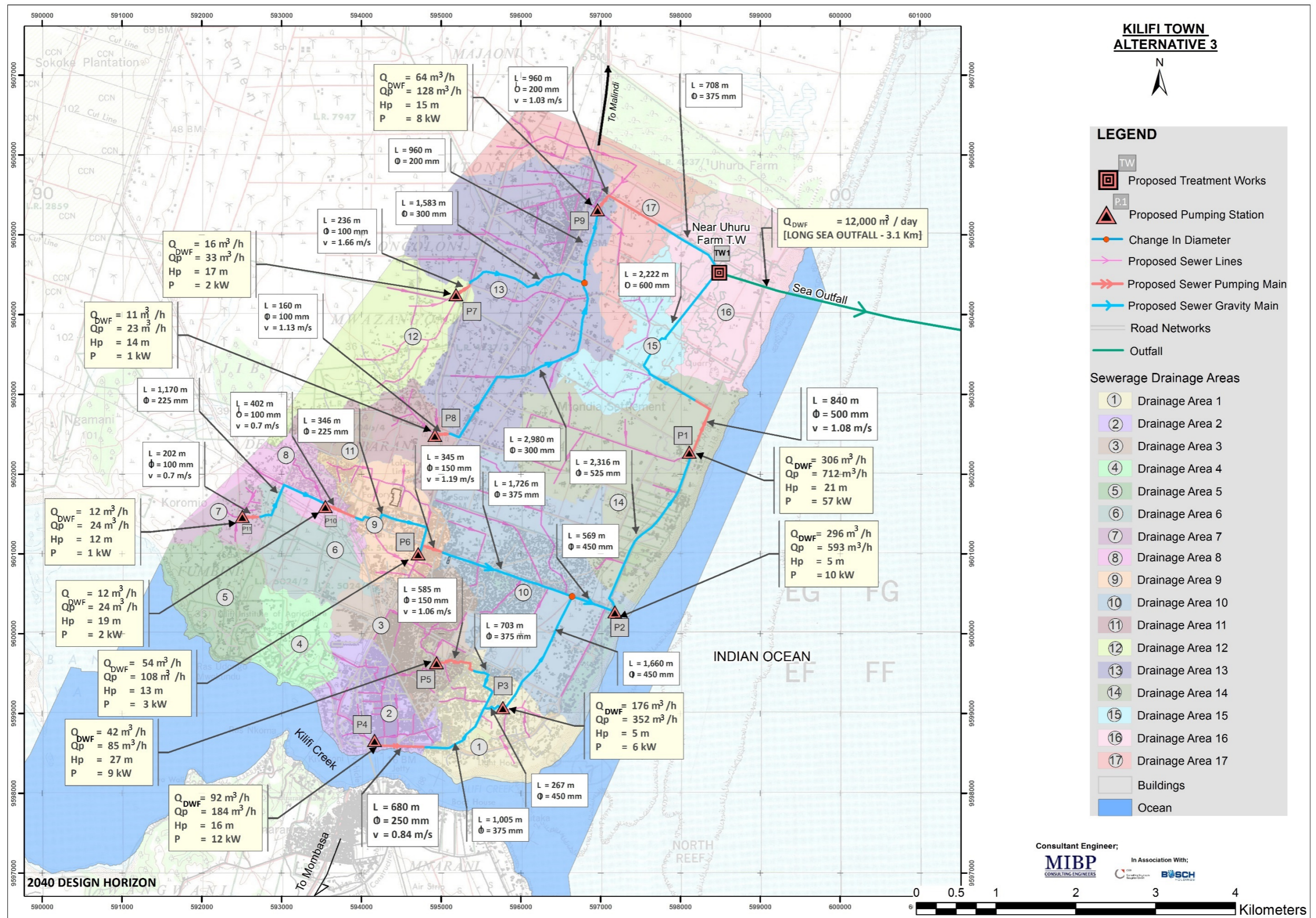
**Figure 7.4: Alternative Scheme 3**

### 7.4    Summary of Alternative Wastewater Management Schemes

A summary of the three Alternative Schemes evaluated for the management of wastewater in Kilifi Town is described in the preceding sub-section (7.3) is given in **Table 7.5** below.

**Table 7.5: Summary of Alternative Wastewater Management Schemes**

| Alternative Scheme | Conveyance System | | Wastewater Treatment Plants | | | |
| | Secondary and Trunk Sewers (km) | No. of Pumping Stations | Location | Design Capacity (m³/day) | Treatment Technology | Land Required (Ha) |
|---|---|---|---|---|---|---|
| 1 | 78,066 | 11 | Uhuru Farm (TW1) | 12,000 | Waste Stabilization Ponds | 30.0 |
| 2 | 76,009 | 10 | Uhuru Farm (TW1) | 2,000 | | 5.0 |
| | | | Baobab (TW2) | 10,000 | | 24.0 |
| 3 | 78,066 | 12 | Uhuru Farm - Sea Outfall | 12,000 | Preliminary Treatment + Sea Outfall | 1.0 |

The locations of the Candidate Wastewater Treatment Sites considered in the considered Alternative Schemes are shown in **Figure 7.5** on **Page 7-10**.

KILIFI TREATMENT WORKS SITES
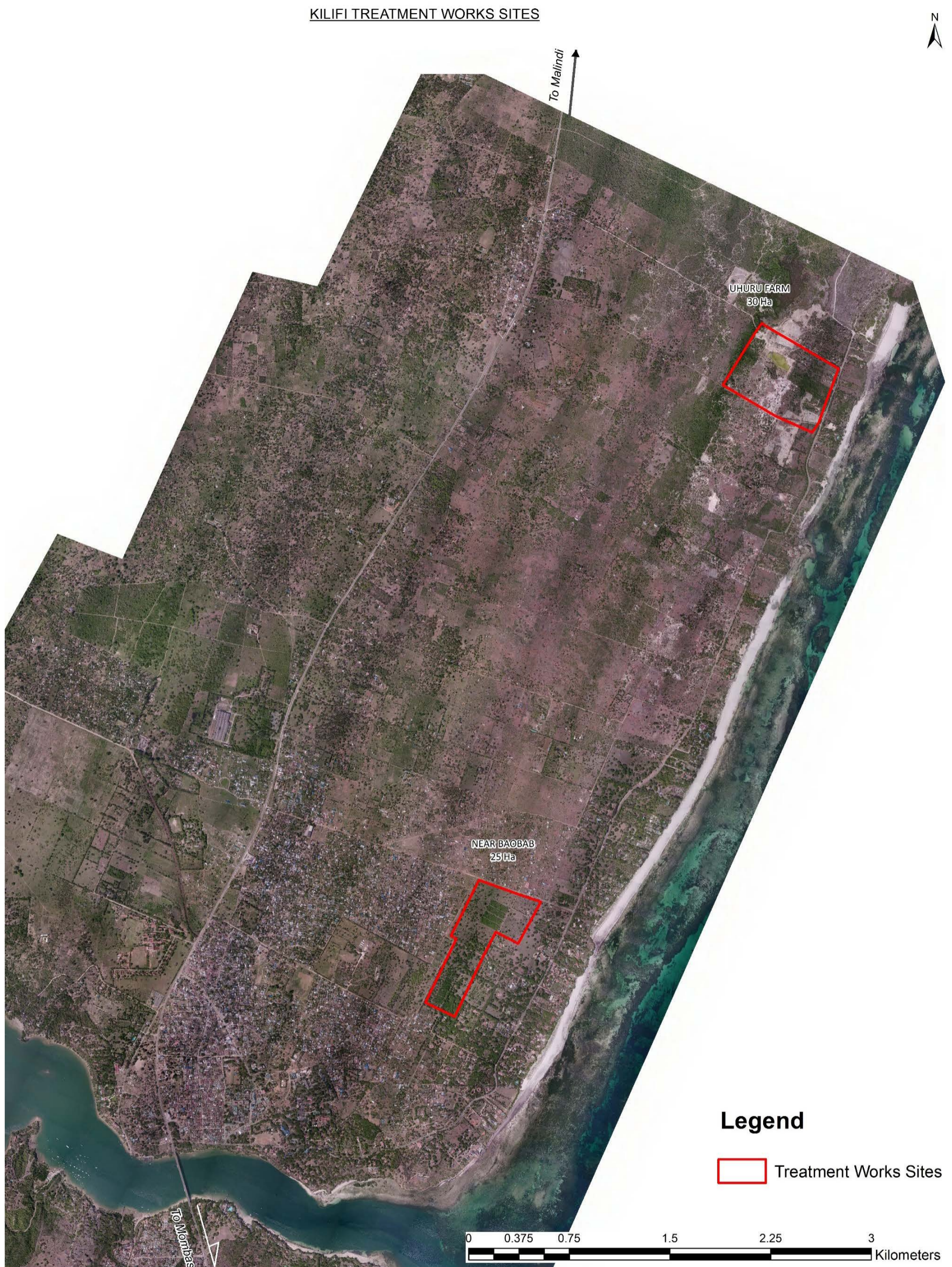


Figure 7.4: Candidate Wastewater Treatment Sites considered in the considered Alternative Schemes

## 8.0    PROJECT COSTS OF THE ALTERNATIVE WASTEWATER MANAGEMENT SCHEMES

### 8.1    Introduction

This Chapter describes the Project Costs of the Alternative Wastewater Management Schemes formulated to serve the sanitation needs of Kilifi Town up to year 2040, including the methodology used to derive them.

The unit costs are based on recent contracts of similar nature in Kenya (2016), supplemented by quotations from various manufacturers and suppliers. All the unit costs are inclusive of relevant duties and taxes but not Preliminary and General Items, Contingencies and Consultancy Fees.

The accuracy of cost estimates is generally plus or minus 20%; which falls within the criteria for estimated costs based on Preliminary Design. However, larger variations are expected for individual works or items or in places where average costs are used.

### 8.2    Unit Costs for Capital Works

### 8.2.1    Basis of Cost Estimates

Capital cost represents the total expenditure incurred in the implementation of the infrastructural components of a Project. It includes the cost of land acquisition, construction and installation, construction contingencies, engineering services, legal and administrative services and financing expenses.

The unit costs of the construction and installation components have been determined from the market prices of the various materials, labour costs, transport and Contractor's overhead and profit. The market prices of the materials have been obtained from various suppliers while labour rates have been obtained from the Joint Building Council of Kenya. All the rates derived have been compared with tender prices for other similar contracts implemented in the recent past. In general, the labour costs have been limited at 20% of the material costs while the Contractor's overhead and profit have been assumed to be 20% of the total costs (cost of material + labour cost).

In this Master Plan, it has been assumed that construction of sewers and the Wastewater Treatment Plant in an implementation phase will be included under a single contract for the benefits which result from the resulting economy of scale; this is more significant on items such as management and site supervision costs.

### 8.2.2    Land Acquisition

The cost of land at various locations within Kilifi depends on the proximity to services and market forces. The average costs of land adopted for the Wastewater Master Plan in Kilifi Town is **Kshs. 5,000,000 per ha** after comparison and assessment of the information of cost of land within the Town collected from the registered Land Valuers and recent land buyers**.**

As earlier described, majority of the proposed sewer have been aligned with public land in the road reserves, easements or right-of-way and river wayleaves. Therefore, land acquisition will mostly apply at the proposed Sewage Pumping Stations and Wastewater Treatment Plants.

In cases where encroachment of structures will be identified on the proposed sewer alignment within the public easements, demolishing of structures for passage of sewers shall be carried out without need for compensation or land acquisition.

### 8.2.3   Construction Cost

This includes cost of materials, equipment, labour and services necessary to construct the Sewerage System (Sewers, Manholes, Pumping Stations) and Wastewater Treatment Plant(s). It covers taxes and duties, and contractor's overhead and profit.

The unit costs for installation of new sewer lines comprises of the following components:

- Site Clearance and Excavation
- Supply of all materials to site
- Pipe lay, joint with rubber rings, granular bedding, test and backfill of trench for flexible-jointed Concrete Pipes
- Pipe lay, joint with rubber rings, granular bedding, test and backfill trench for Steel pipes
- Construction of manholes on the sewer lines
- Contractor's overheads and profits

**Table 8.1** below shows the unit cost for different sizes of flexible jointed sewer lines, manholes and steel pipelines including taxes, duties and contractor's overheads and profit.

**Table 8.1: Unit Costs for Sewer Lines and Manholes**

|   | Item Description | Unit | Unit rate (Kshs) |
|---|---|---|---|
| **A** | **_Flexible jointed precast concrete pipes excluding excavation_** | | |
| | -225mm dia. S&S | m | 1,800 |
| | -300mm dia. S&S | m | 2,040 |
| | - 375mm dia. S&S | m | 2800 |
| | - 450mm dia. S&S | m | 4,900 |
| | - 525mm dia. S&S | m | 5800 |
| | - 600mm dia. S&S | m | 7,200 |
| | - 750mm dia. S&S | m | 10,500 |
| **B** | **_Steel Pipe – NP 10_** | | |
| | - 100mm nominal dia. | m | 2,911 |
| | - 150mm nominal dia. | m | 4,426 |
| | - 200mm nominal dia. | m | 5,593 |
| | - 250mm nominal dia. | m | 9,966 |
| | - 300mm nominal dia. | m | 12,716 |
| | - 350mm nominal dia. | m | 14,090 |
| | - 400mm nominal dia. | m | 17,186 |
| | - 450mm nominal dia. | m | 18,552 |
| | - 500mm nominal dia. | m | 20,707 |
| | - 600mm nominal dia. | m | 26,456 |
| | - 700mm nominal dia. | m | 33,124 |
| | - 800mm nominal dia. | m | 41,104 |
| | - 900mm nominal dia. | m | 50,094 |
| | - 1000mm nominal dia. | m | 61,176 |
| **C** | **_Manholes - 1200mm dia. Precast rings with triangular heavy duty concrete filled mild steel covers_** | | |
| | - Depth n.e. 1.0m | Nr | 104,000 |
| | - Depth n.e. 2.0m | Nr | 118,000 |
| | - Depth n.e. 3.0m | Nr | 148,000 |
| | - Depth n.e. 4.0m | Nr | 173,000 |
| | - Depth n.e. 5.0m | Nr | 198,000 |
| | - Depth n.e. 6.0m | Nr | 224,000 |

Since the depth of excavation of the sewer lines varies considerably, depending on several factors like ground slopes, flow, velocity, etc., the cost of excavation has not been built in the above unit rates.

To consider the variation of trench excavation for different depths, the cost of excavation has been taken separately as shown in **Table 8.2** below. Cost for extra-over excavation in soft and hard rock has also been given.

**Table 8.2: Unit Cost for Trench Excavations for Sewer Lines**

| Pipe Diameter (mm) | Unit Rate (Kshs) | | | | | |
| | Depth Not Exceeding | | | | | |
| | 1.0m | 2.0m | 3.0m | 4.0m | 5.0m | 6.0m |
|---|---|---|---|---|---|---|
| 225 | 243 | 365 | 609 | 937 | 1,205 | 1,473 |
| 300 | 278 | 417 | 696 | 1,071 | 1,377 | 1,683 |
| 375 | 313 | 469 | 782 | 1,205 | 1,549 | 1894 |
| 450 | 348 | 522 | 869 | 1,339 | 1,721 | 2,104 |
| 525 | 383 | 574 | 956 | 1,473 | 1,894 | 2,314 |
| 600 | 417 | 626 | 1,043 | 1,607 | 2,066 | 2,525 |
| 675 | 452 | 678 | 1,130 | 1,741 | 2,238 | 2,735 |
| 750 | 487 | 730 | 1,217 | 1,874 | 2,410 | 2,946 |
| 825 | 522 | 782 | 1,304 | 2,008 | 2,582 | 3,156 |
| 900 | 556 | 835 | 1,391 | 2,142 | 2,754 | 3,366 |

Hard rock - Kshs. 3,200/= per cubic metre

Soft rock - Kshs. 1,800/= per cubic metre

**Figure 8.1** below shows variations of unit costs for sewer trench excavation for various diameters of sewers.
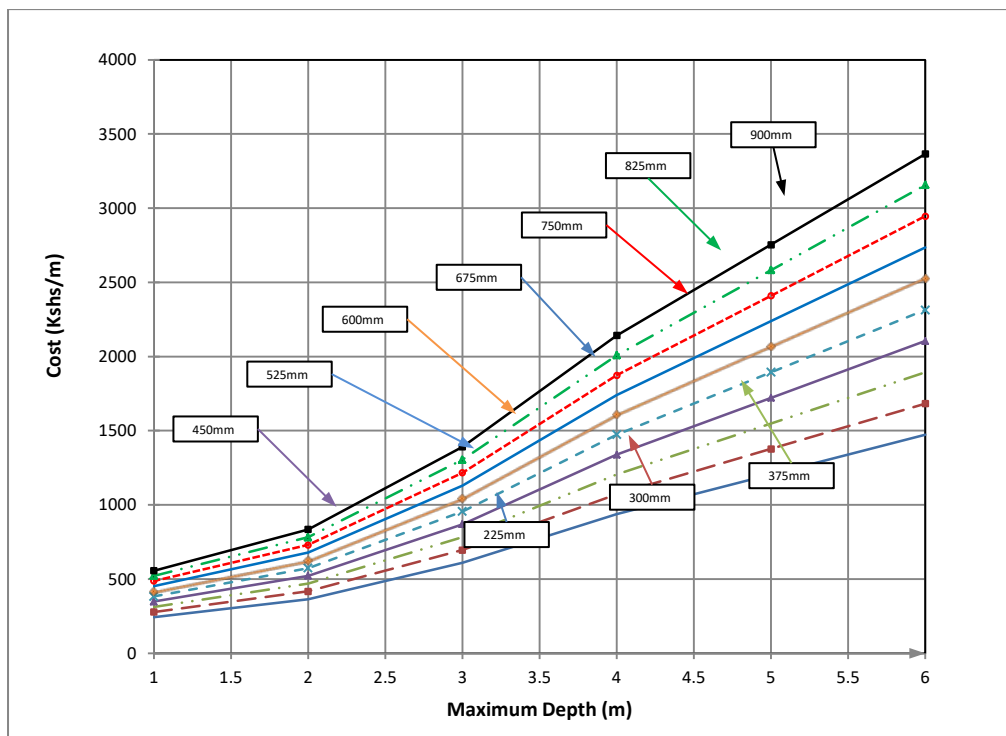


**Figure 8.1: Unit cost for sewer excavation with Depth**

Unit costs considered in the development of rate for Manholes or for any Pumping Station forming part of the Sewer Network are given in **Tables 8.3** to **8.9** below.

**Table 8.3: Unit Cost for Earthworks**

| Item Description | Unit | Rate (Kshs) |
|---|---|---|
| Mass Excavation | | |
| 1) Excavate to spoil | m$^3$ | 297 |
| 2) Excavate and fill | m$^3$ | 320 |
| 3) Excavate in soft rock (E.O) | m$^3$ | 1,800 |
| 4) Excavate in hard rock (E.O) | m$^3$ | 3,200 |
| 5) Imported fill | m$^3$ | 450 |

**Table 8.4: Unit Cost for Concrete and Mortar**

| Design Mix | Unit | Rate (Kshs) |
|---|---|---|
| 1. Grade 25 (1:1.5:3) | m$^3$ | 19,965 |
| 2. Grade 20 (1:2:4) | m$^3$ | 15,255 |
| 3. Grade 15 (1:3:6) | m$^3$ | 13,965 |
| 4. Blinding, 75mm | m$^2$ | 1,050 |

**Table 8.5: Unit Cost for Formwork**

| Item | Unit | Rate (Kshs) |
|---|---|---|
| 1. Wrought Formwork | m$^2$ | 1,750 |
| 2. Rough Formwork | m$^2$ | 1,200 |

**Table 8.6: Unit Cost for Steel Reinforcement**

| Item | Unit | Rate (Kshs) |
|---|---|---|
| 1. Mild Steel 12mm dia. and less | kg | 125 |
| 2. Mild Steel 16mm dia. and less | kg | 125 |
| 3. High Tensile Steel 12mm dia. and less | kg | 125 |
| 4. High Tensile Steel 16mm dia. and over | kg | 125 |
| 5. B.R.C Type A142 (2.22 kg/m$^2$) | m$^2$ | 750 |

**Table 8.7: Unit Cost for Masonry and Block Walling**

| Item | Unit | Rate (Kshs) |
|---|---|---|
| Block Walling (Metric) | | |
| 90mm Blocks | m$^2$ | 1,940 |
| 140mm Blocks | m$^2$ | 2,400 |
| 190mm Blocks | m$^2$ | 2,800 |
| 240mm Blocks | m$^2$ | 3,200 |

**Table 8.8: Unit Cost for Miscellaneous**

| Item | Unit | Rate (Kshs) |
|---|---|---|
| 1. Staff Houses (High Grade) | m$^2$ | 28,000 |
| 2. Staff Houses (Medium Grade) | m$^2$ | 24,000 |
| 3. Staff Houses (Low Grade) | m$^2$ | 22,000 |
| 4. Main Electricity Supply Line | km | 1,600,000 |
| 5. Chain link fencing on Concrete Poles (1.8m high) | m2 | 3,250 |
| 6. Metal Gate (4.0m wide) | Nr | 92,000 |
| 7. Access Road including side drain and footpath (5.5m wide bitumen standard, kerbs, channels, etc.) | km | 60,000,000 |
| 8. -Ditto- (double seal) | km | 45,000,000 |

**Table 8.9: Unit Cost for Electro-Mechanical Works**

| Item | Unit | Cost of M&E as a % of Total Construction Cost |
|---|---|---|
| 1. Waste Stabilization Ponds | % | 5 |
| 2. Trickling Filters | % | 20 |
| 3. Activated Sludge | % | 35 |
| 4. Sea Outfalls | % | 10 |
| 5. Oxidation Ditch | % | 30 |

#### 8.2.3.1 Pumping Stations

Pumping stations comprise of the three main components of urban schemes; (a) Civil Works (b) Electrical Works (c) Mechanical Components i.e. pumps, valves, etc.

The size of the pumping station depends on the designed flows and head and the type and specification of the pumps and motors to be installed.

For preliminary cost estimates, the unit cost of pumping stations has been based on Contractor's rates of recent projects. Where possible, quotations obtained from renown suppliers have been used.

### 8.3    Unit Costs for Operation and Maintenance

#### 8.3.1    General

The cost of Operation and Maintenance (O&M) of each viable alternative scheme is a very important factor in the selection of the recommended alternative. The component of the Operation and Maintenance costs includes:

1. Equipment maintenance and repairs e.g., pumps, motors, etc.
2. Power / Electricity charges
3. Staff wages and salaries
4. Cost of Chemicals

#### 8.3.2    Equipment Maintenance and Repairs

The cost of equipment maintenance and repairs can be estimated as a percentage of the initial capital costs. In the development of this Wastewater Master Plan, it is assumed that annual maintenance cost is 1% of the costs of Civil Works and 5% of the Electro-mechanical Works.

#### 8.3.3    Power Charges

The cost of power consumed has been calculated using unit cost rate of Kshs. <u>18 per kilo watt-hour (kWh)</u>.

#### 8.3.4    Chemical Costs

Where applicable, the cost of chemicals such as chlorine which are for usage at the Wastewater Treatment Plant has been calculated as a percentage of the overall operation and maintenance cost.

### 8.4    Capital and Operations & Maintenance Costs of the Alternative Schemes

### 8.4.1    Capital Costs

The Capital Costs for the three Alternative Schemes formulated for Kilifi Town have been worked out on the following basis;

c) Project Implementation planned to be carried out in two phases i.e. Medium-Term Plan (2020 -2025) and Long-Term Plan (2026 - 2040)

d) The Cost of Civil Works constitute the following fraction of the components total costs;
- Wastewater Treatment Plant - 95%
- Pumping Station - 60%
- Sewers - 100%

A summary of the Capital Costs for the Alternative Schemes is given in **Table 8.10** below;

**Table 8.10: Capital Costs for Alternative Schemes**

| S/No. | Component | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| **1** | **Land Acquisition (Kshs)** | **150,000,000** | **151,670,156** | **15,050,000** |
| **2** | **Civil Works (Kshs)** | **3,111,131,388** | **3,149,997,089** | **3,721,982,995** |
| 2.1 | Sewage Treatment Plant (Kshs) | 1,174,377,159 | 1,188,078,226 | 1,773,645,427 |
| 2.2 | Pumping Stations (Kshs) | 81,795,510 | 134,751,953 | 93,378,849 |
| 2.3 | Sewers (Kshs) | 1,854,958,719 | 1,827,166,910 | 1,854,958,719 |
| **3** | **Electro-Mechanical Works (Kshs)** | **116,339,664** | **152,365,068** | **155,602,325** |
| 3.1 | Sewage Treatment Plant (Kshs) | 61,809,324 | 62,530,433 | 93,349,759 |
| 3.2 | Pumping Stations (Kshs) | 54,530,340 | 89,834,635 | 62,252,566 |
| | **Total Capital Cost (Kshs)** | **3,377,471,052** | **3,454,032,313** | **3,892,635,321** |
| | **Total Capital Cost (USD)** [1] | **32,790,981** | **33,534,294** | **37,792,576** |

### 8.4.2    Operations and Maintenance Costs

The Operations and Maintenance Costs for the two Alternative Schemes formulated for Kilifi Town have been worked out on the following basis;

d) Electricity Costs at the Pumping Stations has been assumed to increase annually at 4.6-4.0% p.a. (same as population) due to increased sewage flow from the increased connections

e) Annual Maintenance Costs of the Schemes have been calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works

f) Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule

A summary of the Annual Operations & Maintenance Costs for the Alternative Schemes in the first year of operation is given in **Table 8.11** below;

**Table 8.11: Annual Operations & Maintenance Costs for Alternative Schemes (Year 1)**

| S/No. | Component | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|
| 1 | Maintenance Costs (Kshs) | 36,928,297 | 39,118,224 | 44,999,946 |
| 2 | Electricity Costs (Kshs) | 3,594,089 | 2,331,301 | 4,551,865 |
| 3 | Staff Costs (Kshs) | 5,064,000 | 7,899,840 | 5,064,000 |
| | **Total Capital Cost (Kshs)** | **45,586,386** | **49,349,365** | **54,615,812** |
| | **Total Capital Cost (USD)** [1] | **442,586** | **479,120** | **530,251** |

[1] – 1 USD = 103 Kshs

## 8.5 Average Incremental costs of the Alternative Schemes

Net Present Value (NPV) is a one of the commonly used criteria for comparing economic viability of projects / Schemes. When the unit NPV of a scheme is derived for the unit of performance indicator, incremental cost (marginal cost) is obtained.

The Net Present Values of the Alternative Schemes have been worked out on the following basis;

- Discount Rate / Cost of Capital - 5%
- Economic Life of Scheme - 30 years
- 10 Years Asset Renewal Period for the Electro-Mechanical components
- Substantial completion of the scheme expected at the end of the 2$^{nd}$ year of Implementation of the Medium-Term Plan Works (2022) and thus, scheme operation to commence in the 3$^{rd}$ year (2023)

From the respective NPVs, Average Incremental Costs have been calculated in consideration of the following factors;

- Treated Wastewater to increase from 6,000 m³/d in year 2028 to 12,000 m³/d in year 2040
- BOD removal as the key performance indicator
- Average Influent BOD$_5$ of 525 mg/l and Effluent BOD$_5$ of 30 mg/l; thus, BOD$_5$ removal of 495 mg/l

Average Incremental Cost of BOD removal within the economic life of the Infrastructure can also be used as a measure of economic viability.

The Net Present Values and the Average Increment Cost of BOD removal of the Alternative Schemes are given in **Table 8.12** below;

**Table 8.12: Net Present Values and Average Incremental Cost of BOD Removal**

| Alternative Scheme | NPV (USD) | Average Incremental Cost of BOD Removal (USD / ton of BOD removed) |
|---|---|---|
| Alt Scheme 1 | 39,661,814 | 1,806 |
| Alt Scheme 2 | 41,411,775 | 1,886 |
| Alt Scheme 3 | 46,286,053 | 2,108 |

## 8.6 Sensitivity Analysis

To ascertain the susceptibility of the ranking of the Alternative Schemes based on the Net Present Values, sensitivity analyses of the Schemes has been carried out by varying the Capital Expenditures (CAPEX) and Operation Expenditures (OPEX).

A summary of the Sensitivity Analysis is given in **Table 8.13** below;

**Table 8.13: Summary of Sensitivity Analysis of the Alternative Schemes**

| Alternative Scheme | NPV (USD) | | | | |
|---|---|---|---|---|---|
| | No Variation in CAPEX & OPEX | Change in CAPEX (Capital Expenditures) | | Change in OPEX (Operations Expenditures) | |
| | | -20% | +20% | -20% | +20% |
| Alt Scheme 1 | 39,661,814 | 32,339,299 | 46,984,330 | 38,240,941 | 41,082,688 |
| Alt Scheme 2 | 41,411,775 | 33,768,333 | 49,055,217 | 39,711,067 | 43,206,805 |
| Alt Scheme 3 | 46,286,053 | 37,416,829 | 55,155,278 | 44,584,069 | 47,988,038 |

## 9.0    MULTI-CRITERIA ANALYSIS AND REVIEW OF DEVELOPMENT STRATEGIES

### 9.1    Introduction to the Adopted Criteria

Selection of an appropriate Wastewater Treatment Train and Wastewater Management Scheme is an important stage in the design of Wastewater Collection and Treatment System. Multi Criteria Decision Making (MCDM) techniques are generally enabled to structure the problem clearly and systematically for the decision makers' to easily examine and scale the problem in accordance with the priorities identified.

This chapter presents an application of the Analytical Hierarchy Process (AHP) for the selection of the most suitable Wastewater Treatment Train and Wastewater Management Scheme for the prevailing conditions in Kilifi Town.

The Analytical Hierarchy Process (AHP), has been adopted to perform the Multi Criteria Analysis because it permits objective focused discussion of the stakeholders' concerns. AHP is a system analysis technique introduced by Professor T.L.A. Saaty of the University of Pittsburgh, Pennsylvania, U.S.A.

### 9.1.1    Methodology of Analytical Hierarchy Process (AHP)

Traditionally the selection of the optimum treatment train or scheme from a number of alternatives is carried out by comparing objectively economical and technical parameters such as Capital Costs, Net Present Values, Dynamic Costs and Technical Considerations of the treatment train /schemes.

To carry out multicriteria analysis in the development of Kilifi Wastewater Master Plan, the economic, technical and environmental parameters of interest have been categorized for ease of comparison. These categories include Ease of Operation and Maintenance, Net Present Value, Environmental Impacts, Land Requirement and Institutional Strength.

AHP is a mathematical process which acts as a tool to simplify the various complex issues through a pairwise comparison of parameters and provides a rationale for ranking parameters thus prompting consensus on the selected alternative. The mathematical process is based on deriving weights for a set of parameters per importance.

A summary of the major steps in carrying out Multi Criteria Analysis by AHP Model is given below.

**Step 1**
A parameter matrix 'B' is constructed by the pairwise comparison of the relative importance of the parameter with respect to the principle objective of selecting the optimum alternative Wastewater Treatment Train.

The scale for the pairwise comparisons is given in **Table 9.1** on **Page 9-2**.

**Step 2**
A n x n decision matrix is constructed for each of the parameters. In the construction of each of the decision variable matrices, pairwise comparisons are carried out between the decision variables with respect to the parameter under consideration.

**Table 9.1: Scale for Pairwise Comparison**

| Intensity of Relative Importance | Definitions | Explanation |
|---|---|---|
| 1 | Equal importance | Two activities contribute equally to the objective |
| 3 | Moderate importance of one over another | Experience and judgement slightly favour one activity over the other |
| 5 | Essential or strong importance | Experience and judgement strongly favoured one activity over another |
| 7 | Demonstrated importance | An activity strongly favoured and its dominance is demonstrated in practice |
| 9 | Extreme importance | The evidence favouring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values between the two adjacent judgements | When compromise is needed |
| Reciprocals of above non-zero numbers | If any activity has one of the above numbers (e.g. 3) compared with a second activity, the second activity has the reciprocal value (i.e. 1/3) when compared to the first | |

**Step 3**

The priority vectors $x_1$, $x_2$, ...$x_4$ for the decision variable matrices are calculated. The priority vectors are taken as the column to form a composite matrix 'C' such that

$$C = (x_1\ x_2\ ...\ ...\ x_4)$$

The composite priority vector $x_c$ is obtained by multiplying the composite matrix C by the priority vector $x_b$ of the parameter matrix i.e $x_c = c * x_b$.

From $x_c$, the relative weights of the decision variables i.e. Alternative Wastewater Treatment Train is obtained. The optimum alternative is the one with the highest weight.

## 9.2     Wastewater Treatment Train Selection

### 9.2.1     Objective Description

The principal objective of this study is to select the 'most suitable wastewater treatment train for Kilifi Town'. This is the core consideration in the formulation of the parameters used in AHP.

### 9.2.2     Parameters

To meet the principal objective, several parameters (subordinate objectives) have been formulated which must be fulfilled. These parameters are identified in the subsequent subsections with their influence on the Treatment Train selection and their characteristics briefly discussed.

#### 9.2.2.1     Simplicity of Operations and Maintenance

This parameter defines the relationship between the level of operation and maintenance skills required and the capability of the local labour pool and service industry.

This factor is very important in consideration of the constraints in the availability of trained manpower, availability of spare parts and the need to prioritise the use of limited financial resources.

Decision variables that can be sustained with the use of affordable and locally available skills have been given higher weights.

### 9.2.2.2 Net Present Value (NPV)

This is an indicative parameter of the total monetary outlay required by a treatment train. It incorporates the Capital Costs and Operations & Maintenance Costs of the Project. A 20 year period has been used in the determination of NPV.

Using the scale for pairwise comparison of decision variables the treatment train with the lowest NPV is assigned the highest weight.

### 9.2.2.3 Environmental Impact

In the selection of the most suitable treatment train, it is important to analyse the effect on the environment. The degree of odour and noise from the treatment train should not exceed the nuisance threshold. This is achieved by such means including provision of a buffer zone planted with trees.

Lower weight is assigned to the treatment trains with greater negative impact.

### 9.2.2.4 Land Requirement

The Land requirement for the treatment train should include allowance for provision of future expansions works has been put into consideration under this parameter. Land requirement should also include a buffer zone between the location of the treatment train and adjacent lands.

A wastewater treatment train with the less land requirement have been given higher weight using the subjective scale of weighting.

### 9.2.2.5 Institutional Strength

The capacity of the utility provider such as manpower, requisite skill of staff, operation & maintenance equipment etc. should correspond to the treatment train adopted for efficient daily running of the treatment facility.

Alternatives which require a lower degree of management effort are weighted higher.

### 9.2.3 Alternative Wastewater Treatment Trains

Alternatives treatment trains considered in the AHP are listed below:

- Alternative 1 - Waste Stabilization Ponds
- Alternative 2 – Composite Biofilters (Trickling Filters) System (Anaerobic Ponds + Trickling Filters + Maturation Ponds)
- Alternative 3 - Composite Oxidation Ditch System (Oxidation Ditch + Maturation Ponds)
- Alternative 4 – Long Sea Outfall

**9.2.4  Hierarchy Decision Model**

The model of AHP developed in the Multi-criteria Analysis is shown in **Figure 9.1** below.
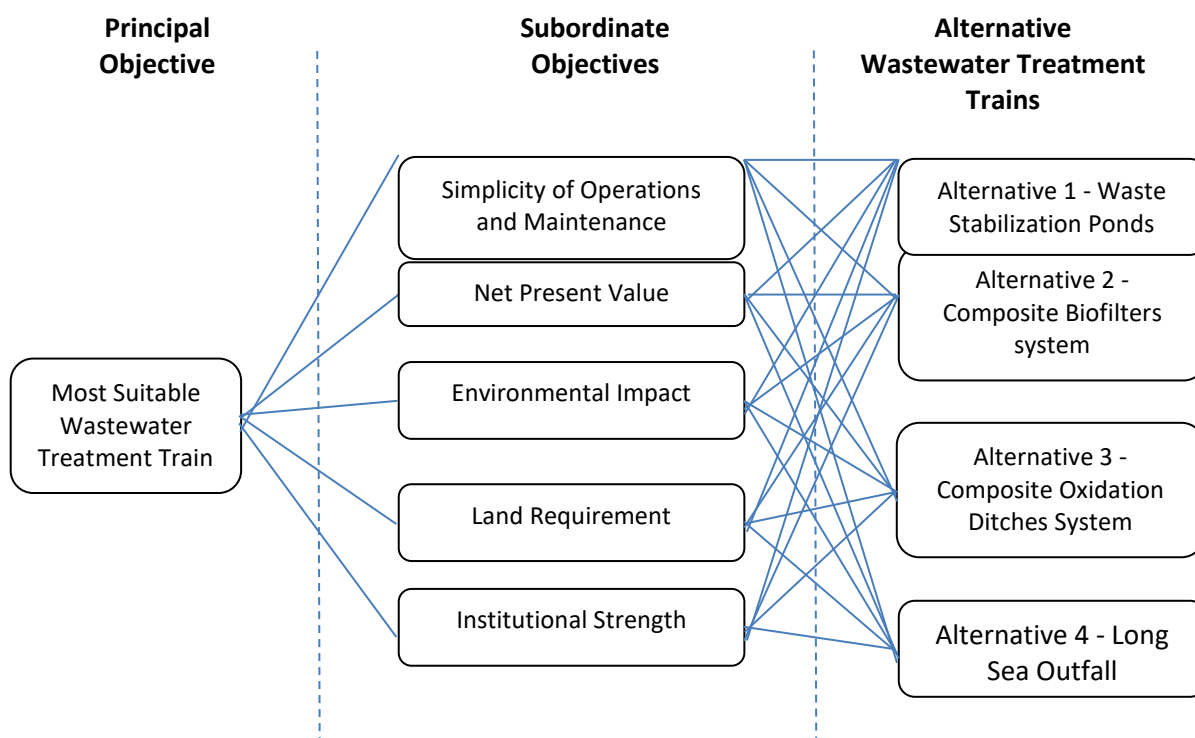


**Figure 9.1: Hierarchy Decision Model used in the AHP**

**9.2.5  Parameter Matrix and Weighting**

In accordance with the methodology, a pairwise comparison has been made on the parameters by addressing the question; "Which parameter /subordinate objective contribute more to the principal objective?"

The subordinate objectives which by cognizance pose greater importance have been assigned higher scales in the Intensity of Relative Importance.

A summary of the resulting matrix of the Parameters is given in **Table 9.2** below.

**Table 9.2: Resultant Matrix of Parameters' Pairwise Comparison**

|  | Simplicity of operation and Maintenance | Net Present Value | Environmental Impacts | Land Requirement | Institutional Strength |
|---|---|---|---|---|---|
| *Simplicity of Operation and Maintenance* | 1 | 1 | 1/3 | 4 | 3 |
| *Net Present Value* | 1 | 1 | 1/3 | 4 | 2 |
| *Environmental Impacts* | 3 | 3 | 1 | 7 | 2 |
| *Land Requirement* | 1/4 | 1/4 | 1/7 | 1 | 1/5 |
| *Institutional Strength* | 1/3 | 1/2 | 1/2 | 5 | 1 |

To illustrate the interpretation of the scales of Intensity of Relative Importance, the weights of Simplicity of Operation and Maintenance against other parameters have been analyzed and summarized in **Table 9.3** below.

**Table 9.3: Analysis of Simplicity of Operation & Maintenance Weights against other Parameters**

| Pairwise Comparison | Weighting | Explanation |
|---|---|---|
| *Simplicity of Operation and Maintenance against NPV* | 1 | Equal Importance |
| *Simplicity of Operation and Maintenance against Environmental Impacts* | 1/3 | Environmental Impacts is moderately more important Simplicity of Operation and Maintenance |
| *Simplicity of Operation and Maintenance against Land Requirement* | 4 | Simplicity of Operation and Maintenance is moderately more important than Land Requirement |
| *Simplicity of Operation and Maintenance against Institutional Strength* | 3 | Simplicity of Operation and Maintenance is moderately more important than Institutional Strength |

A priority vector analyses the comparative weights of all the parameters for ranking purposes. A summary of the priority vectors and ranking for the parameters is given in **Table 9.4** below.

**Table 9.4: A summary of the Priority Vectors for Parameter Matrix**

| Decision variable | Priority Vector | % Best | Ranking % |
|---|---|---|---|
| Simplicity of Operation and Maintenance | 0.222 | 22% | 2 |
| Net Present Value | 0.191 | 19% | 3 |
| Environmental Impacts | 0.410 | 41% | 1 |
| Land Requirements | 0.042 | 4% | 5 |
| Institutional Strength | 0.135 | 13% | 4 |

From **Table 9.4** above, it can be deduced that Environmental Impact is the most significant parameter in the selection of the most suitable wastewater treatment train. Simplicity of Operation & Maintenance and Net Present Values also have pronounced significance.

However, Land Requirement has least influence in the selection of most suitable treatment train.

**Table 9.5** below gives a summary of the parameters' strengths against the alternative wastewater treatment trains.

**Table 9.5: Summary of Parameter Weighting against Alternative Wastewater Treatment Trains**

| | Simplicity of Operations and Maintenance | Net Present Value | Environmental Impacts | Land Requirement | Institutional Strength |
|---|---|---|---|---|---|
| *Waste Stabilization Ponds* | Excellent | Excellent | Excellent | Poor | Good |
| *Composite Biofilters* | Fair | Good | Good | Fair | Fair |
| *Composite Oxidation Ditches* | Fair | Fair | Fair | Good | Fair |
| *Long Sea Outfall* | Good | Poor | Fair | Excellent | Good |

Based on these strengths, decision variable matrices for each of the five parameters have been prepared.

The decision matrices for the significant parameters of Environmental Impact, Simplicity of Operations & Maintenance and Net Present Value are given in **Tables 9.6 to 9.8** on **Page 9-6.** Detailed decision matrices for all the parameters is given in Volume 2 of this Report.

**Table 9.6: Decision Variable Matrix based on Environmental Impact**

|  | Waste Stabilization Ponds | Composite Biofilters | Composite Oxidation Ditches | Long Sea Outfall |
|---|---|---|---|---|
| Waste Stabilization Ponds | 1 | 2 | 3 | 3 |
| Composite Biofilters | 1/2 | 1 | 2 | 2 |
| Composite Oxidation Ditches | 1/3 | 1/2 | 1 | 1 |
| Long Sea Outfall | 1/3 | 1/2 | 1 | 1 |

**Table 9.7: Decision Variable Matrix based on Simplicity of Operation & Maintenance**

|  | Waste Stabilization Ponds | Composite Biofilters | Composite Oxidation Ditches | Long Sea Outfall |
|---|---|---|---|---|
| Waste Stabilization Ponds | 1 | 4 | 4 | 2 |
| Composite Biofilters | 1/4 | 1 | 1 | 1/3 |
| Composite Oxidation Ditches | 1/4 | 1 | 1 | 1/3 |
| Long Sea Outfall | 1/2 | 3 | 3 | 1 |

**Table 9.8: Decision Variable Matrix based on Net Present Value**

|  | Waste Stabilization Ponds | Composite Biofilters | Composite Oxidation Ditches | Long Sea Outfall |
|---|---|---|---|---|
| Waste Stabilization Ponds | 1 | 3 | 4 | 5 |
| Composite Biofilters | 1/3 | 1 | 2 | 3 |
| Composite Oxidation Ditches | 1/4 | 1/2 | 1 | 2 |
| Long Sea Outfall | 1/5 | 1/3 | 1/2 | 1 |

### 9.2.6 Ranking of Alternatives Wastewater Treatment Trains

The composite matrices derived from decision variables when multiplied with the corresponding priority vectors result to weighted totals of the alternatives under consideration. A summary of the weighted totals for the alternative wastewater treatment trains is given in **Table 9.9** below.

**Table 9.9: Weighted Totals for the alternative wastewater treatment trains**

|  | Simplicity of Operations and Maintenance | Net Present Value | Environmental Impacts | Land Requirement | Institutional Strength | Weighted Total | Rank |
|---|---|---|---|---|---|---|---|
| Waste Stabilization Ponds | 0.486 | 0.548 | 0.456 | 0.052 | 0.410 | 0.457 | 1 |
| Composite Biofilters | 0.11 | 0.23 | 0.26 | 0.09 | 0.13 | 0.198 | 3 |
| Composite Oxidation Ditches | 0.108 | 0.136 | 0.141 | 0.192 | 0.085 | 0.127 | 4 |
| Long Sea Outfall | 0.30 | 0.08 | 0.14 | 0.66 | 0.37 | 0.218 | 2 |

### 9.2.7   Recommendation for Wastewater Treatment Train

From the Multi-criteria Analysis, it has been found out that Environmental Impacts, Simplicity of Operations & Maintenance and Net Present Value are the main determinants in the selection of wastewater treatment train.

**On this basis, Waste Stabilization Ponds System is the most suitable wastewater treatment train and is recommended for Kilifi Wastewater Management Scheme.**

### 9.3   Site Identification and Selection

An ideal site for a Wastewater Treatment Plant (WWTP) is one with the minimal environmental effects and associated with low capital costs and operation & maintenance requirements.

Several parameters describe the requirements of such ideal WWTP sites and a systematic and unbiased analysis is necessary for an objective and robust site selection.

### 9.3.1   Criteria for Site Selection

Parameters considered in the site selection for WWTP in Kilifi are briefly described below;

#### 9.3.1.1   Land-Use

In the Land-use Map, different areas of Kilifi Town have been assigned varied existing and proposed uses. Areas earmarked for residential, industries, agriculture, forests and social amenities are considered less suitable for the location of a Wastewater Treatment Plant (WWTP). On the other hand, public utility or undeveloped Agricultural Land located away from the sensitive residential areas are preferred.

#### 9.3.1.2   Distance of Effluent Discharge Point

The distance from the WWTP site to the final receiving environment such as the river and ocean, is an important consideration in site selection. Preference is given to the sites that require shorter lengths of Outfall Sewers.

#### 9.3.1.3   Topography of the Sewered Area

An ideal WWTP site should be located on a low-lying area of the sewerage system for gravity conveyance. Otherwise, pumping stations become necessary thereby increasing both capital cost and the operation and maintenance requirements of the sewerage system.

#### 9.3.1.4   Topography of Site

The slope at an ideal site should permit the gravity flow within the WWTP without requiring excessive excavations for the structures. Slopes less than 1:20 are preferred.

#### 9.3.1.5   Geological Conditions

A site with low water table and whose soils are impermeable is considered ideal with respect to geological considerations. For instance, silt or clay soils are suitable for pond construction.

More often, the geological formation within a Town is fairly similar. For instance, all the candidate sites in Kilifi Town comprise of a mixture of well drained, deep, dark red to reddish brown, friable, sandy clay loam to sandy clay, with top soil of loamy sand and well drained, very deep, yellowish red, very friable, fine sandy loam to fine sandy clay loam. These soils are suitable for WWTP (Waste Stabilization Ponds) construction.

#### 9.3.1.6   Existing Infrastructure

Proximity to infrastructural systems such as roads, electricity and portable water is sought for while siting for a WWTP location. It reduces cost of construction and operation & maintenance requirements of the WWTP. Sites that are closer to existing infrastructure are preferred.

#### 9.3.1.7 Potential for reuse of treated wastewater

Treated wastewater can be reused for beneficial purposes such as agricultural irrigation, industrial processes, ground water recharge, etc. Proximity to the potential re-use application and relative elevation difference (for gravity conveyance) is preferred in siting of WWTP. For instance, downstream arable land would make a WWTP site ideal for agricultural irrigation.

#### 9.3.1.8 Land Acquisition

In this criterion, preference is given to sites owned by government agencies such as Ministries, County Governments, etc. This ensures that the project affected persons are kept to a minimal and reduces the cost of resettlement and compensation.

### 9.3.2 Candidate Sites

Two aalternative WWTP sites have been analysed to select the most suitable for Kilifi Town. A brief description of these sites is given below;

#### 9.3.2.1 Uhuru Farm (Bofa/Maweni) Site

This site is located on a dis-used quarry at Uhuru Farm within Bofa/Maweni location. It is accessible from Kilifi town using Bofa Road to Uhuru Farm. It slopes towards the Indian Ocean beach and exhibits ASAL characteristics.

The main socio economic activity in the area is subsistence farming and livestock rearing. The area is sparsely populated.

#### 9.3.2.2 Baobab (Hospital/Nayeni) Site

The site, located within Nayeni Estate in Baobab area is accessible via the Mombasa - Garissa Road (B8 Road). It is located within a residential area and the proposed site is owned by individuals.

### 9.3.3 Evaluation of Candidate Sites

The above sites have been evaluated based on the listed criteria to determine the suitability ranking. A summary of the evaluation is given in **Table 9.10** below.

**Table 9.10: Evaluation of Candidate Wastewater Treatment Plant Sites**

|  | Land use | Distance of Effluent Discharge Point from the WWTP | Topography of Sewered Area | Topography of Site | Geological Conditions | Existing Infrastructure | Potential for Wastewater reuse | Project Affected Persons |
|---|---|---|---|---|---|---|---|---|
| Uhuru Farm | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ |
| Baobab Site | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |

Multicriteria Analysis of the candidate sites has been incorporated in the analysis of the Alternative Schemes in the subsequent section.

## 9.4 Wastewater Management Scheme Selection Analysis

### 9.4.1 Objective Description

The principal objective of this study is to select the most suitable wastewater management scheme for Kilifi Town.

### 9.4.2 Parameters

To meet the principal objective, several parameters (subordinate objectives) must be fulfilled. These are listed below with brief description of their influence and characteristics.

#### 9.4.2.1 Simplicity of Operations and Maintenance

This parameter defines the relationship between the level of operation and maintenance skills required and the capability of the local labour pool and service industry. It is an important parameter in consideration of constraints in the availability of trained manpower and spare parts and the need to prioritise the use of limited financial resources.

Decision variables that can be sustained by affordable and locally available skills have been given higher weights.

#### 9.4.2.2 Net Present Value (NPV)

This is an indication of the total monetary outlay for scheme incorporating the capital cost and operation and maintenance requirements. A 20 year-period has been used for NPV calculation.

Using the scale for pairwise comparison, a decision variable with lower NPV has been assigned a higher weight.

#### 9.4.2.3 Environmental Impact

Environmental impact of the scheme is important in the selection of the most suitable wastewater management scheme. The degree of odour and noise should not exceed nuisance threshold.

Lower weights are assigned to schemes with greater negative environmental impact.

#### 9.4.2.4 Potential for Wastewater Reuse

Treated wastewater can be reused for beneficial purposes such as agricultural irrigation, industrial processes, ground water recharge, etc. Proximity to the potential re-use application and relative elevation difference (for gravity conveyance) is preferred in siting of WWTP. For instance, downstream arable land would give a scheme a higher ranking with respect to agricultural irrigation.

#### 9.4.2.5 Land Acquisition

In this criterion, preference is given to schemes whose land requirements lie on sites owned by government agencies such as Ministries, County Governments, etc. This ensures that the project affected persons are kept to a minimal and reduces the cost of resettlement and compensation.

#### 9.4.2.6 Land use

In the Land-use Map, different areas of Kilifi Town have been assigned varied existing and proposed uses. Areas earmarked for residential, industries, agriculture, forests and social amenities are considered less suitable for the location of a Wastewater Treatment Plant (WWTP). On the other hand, public utility or undeveloped Agricultural Land located away from the sensitive residential areas are preferred.

These have been considered in the selection of the wastewater management scheme.

### 9.4.3 Alternative Wastewater Management Schemes

Three alternatives Wastewater Management Schemes formulated for Kilifi Town are summarized in **Table 9.11** below:

**Table 9.11: Alternative Wastewater Management Schemes**

| Alternative Scheme | Description |
|---|---|
| Alternative 1 | • Centralized Scheme with 1 Nr. Wastewater Treatment Plant at Uhuru Farm (ultimate capacity 12,000m³/d), comprising of Waste Stabilization Ponds & 11 Nr. Pumping Stations |
| Alternative 2 | • Decentralized Scheme with 2 Nr. Wastewater Treatment Plants at Uhuru Farm (ultimate capacity 2,000m³/d), and Baobab /Nayeni Site (ultimate capacity 10,000m³/d), both Waste Stabilization Ponds & 11 Nr. Pumping Stations |
| Alternative 3 | • Centralized Scheme with Preliminary Treatment Plant and Long Sea Outfall at Uhuru Farm & 12 Nr. Pumping Stations (ultimate capacity 12,000m³/d, 3.1km long sea outfall) |

### 9.4.4 Parameter Matrix and Weighting

In accordance with the methodology, a pairwise comparison has been made on the parameters by addressing the question; "Which parameter /subordinate objective contribute more to the principal objective?"

The subordinate objectives which by cognizance pose greater importance have been assigned higher scales in the Intensity of Relative Importance.

A summary of the resulting matrix of the Parameters is given in **Table 9.12** below.

**Table 9.12: Resultant Matrix of Parameters' Pairwise Comparison**

| | Simplicity of operation and Maintenance | Net Present Value | Environmental Impacts | Potential for Wastewater Reuse | Land Acquisition | Land Use |
|---|---|---|---|---|---|---|
| *Simplicity of operation and Maintenance* | 1 | 2 | 1/2 | 3 | 1/2 | 2 |
| *Net Present Value* | 1/2 | 1 | 1/2 | 3 | 1/2 | 3 |
| *Environmental Impacts* | 2 | 2 | 1 | 4 | 2 | 3 |
| *Potential for Wastewater Reuse* | 1/3 | 1/3 | 1/4 | 1 | 1/4 | 1/3 |
| *Land Acquisition* | 2 | 2 | 1/2 | 4 | 1 | 2 |
| *Land Use* | 1/2 | 1/3 | 1/3 | 3 | 1/2 | 1 |

To illustrate the interpretation of the scales of Intensity of Relative Importance, the weights of Simplicity of Operation and Maintenance against other parameters have been analyzed and summarized in **Table 9.13** on **Page 9-11**.

**Table 9.13: Analysis of Simplicity of Operation & Maintenance Weights against other parameters**

| Pairwise Comparison | Weighting | Explanation |
|---|---|---|
| Simplicity of Operation and Maintenance against NPV | 2 | Simplicity of Operation and Maintenance is slightly more important NPV |
| Simplicity of Operation and Maintenance against Environmental Impacts | 1/2 | Environmental Impacts is slightly more important Simplicity of Operation and Maintenance |
| Simplicity of Operation and Maintenance against Potential for Reuse | 3 | Simplicity of Operation and Maintenance is moderately more important than Potential for Reuse |
| Simplicity of Operation and Maintenance against Land Acquisition | 1/2 | Land Acquisition is slightly more important than Simplicity of Operation and Maintenance |
| Simplicity of Operation and Maintenance against Land Use | 2 | Simplicity of Operation and Maintenance is moderately more important than Land Use |

A priority vector analyses the comparative weights of all the parameters for ranking purposes. A summary of the priority vectors and ranking for the parameters is given in **Table 9.14** below.

**Table 9.14: A summary of the priority vectors for Parameter Matrix**

| Decision variable | Priority Vector | % Best | Ranking % |
|---|---|---|---|
| Simplicity of Operation and Maintenance | 0.175 | 17.50% | 3 |
| Net Present Value | 0.153 | 15.30% | 4 |
| Environmental Impacts | 0.301 | 30.10% | 1 |
| Potential for Reuse | 0.050 | 5.00% | 6 |
| Land Acquisition | 0.227 | 22.70% | 2 |
| Land Use | 0.094 | 9.40% | 5 |

From **Table 9.14** above, it can be deduced that Environmental Impact is the most significant parameter in the selection of the most suitable Wastewater Management Scheme. Land Acquisition, Simplicity of Operation & Maintenance and Net Present Value also have pronounced significance.

However, Potential for Treated Wastewater Reuse and Land Use Pattern have the least influence in the selection of most suitable Wastewater Management Scheme.

**Table 9.15** below gives a summary of the parameters' strengths against the alternative schemes.

**Table 9.15: Summary of Parameter Weighting against alternative schemes**

| | Simplicity of Operations and Maintenance | Net Present Value | Environmental Impacts | Potential for Reuse | Land Acquisition | Land Use |
|---|---|---|---|---|---|---|
| *Centralized Scheme with 1 Nr WSP System* | Very Good | Very Good | Good | Good | Good | Good |
| *Decentralized Scheme with 2Nr WSP System* | Fair | Good | Good | Good | Fair | Poor |
| *Centralized Scheme with Long Sea Outfall* | Good | Fair | Fair | Poor | Good | Good |

Based on these strengths, decision variable matrices for each of the five parameters have been prepared.

The decision matrices for the significant parameters of Environmental Impact, Land Acquisition, Simplicity of Operations & Maintenance and Net Present Value are given in **Tables 9.16 to 9.19** below.

Detailed decision matrices for all the parameters is given in **Volume 2 of this Report**.

**Table 9.16: Decision Variable Matrix based on Environmental Impact**

|  | Centralized Scheme with 1 Nr WSP System | Decentralized Scheme with 2Nr WSP System | Centralized Scheme with Long Sea Outfall |
|---|---|---|---|
| Centralized Scheme with 1 Nr WSP System | 1 | 2 | 3 |
| Decentralized Scheme with 2Nr WSP System | 1/2 | 1 | 2 |
| Centralized Scheme with Long Sea Outfall | 1/3 | 1/2 | 1 |

**Table 9.17: Decision Variable Matrix based on Land Acquisition**

|  | Centralized Scheme with 1 Nr WSP System | Decentralized Scheme with 2Nr WSP System | Centralized Scheme with Long Sea Outfall |
|---|---|---|---|
| Centralized Scheme with 1 Nr WSP System | 1 | 3 | 1 |
| Decentralized Scheme with 2Nr WSP System | 1/3 | 1 | 1/3 |
| Centralized Scheme with Long Sea Outfall | 1 | 3 | 1 |

**Table 9.18: Decision Variable Matrix based on Simplicity of Operations & Maintenance**

|  | Centralized Scheme with 1 Nr WSP System | Decentralized Scheme with 2Nr WSP System | Centralized Scheme with Long Sea Outfall |
|---|---|---|---|
| Centralized Scheme with 1 Nr WSP System | 1 | 3 | 2 |
| Decentralized Scheme with 2Nr WSP System | 1/3 | 1 | 1/2 |
| Centralized Scheme with Long Sea Outfall | 1/2 | 2 | 1 |

**Table 9.19: Decision Variable Matrix based on Net Present Value**

|  | Centralized Scheme with 1 Nr WSP System | Decentralized Scheme with 2Nr WSP System | Centralized Scheme with Long Sea Outfall |
|---|---|---|---|
| Centralized Scheme with 1 Nr WSP System | 1 | 3 | 5 |
| Decentralized Scheme with 2Nr WSP System | 1/3 | 1 | 3 |
| Centralized Scheme with Long Sea Outfall | 1/5 | 1/3 | 1 |

### 9.4.5    Ranking of Alternatives Wastewater Treatment Trains

The composite matrices derived from decision variables when multiplied with the corresponding priority vectors result to weighted totals of the alternatives under consideration. A summary of the weighted totals for the alternative schemes is given in **Table 9.20** below.

**Table 9.20: Weighted Totals for the alternative schemes**

|  | Simplicity of Operations and Maintenance | Net Present Value | Environmental Impacts | Potential for Reuse | Land Acquisition | Land Use | Weighted Totals | Rank |
|---|---|---|---|---|---|---|---|---|
| *Centralized Scheme with 1 Nr WSP System* | 0.175 | 0.153 | 0.301 | 0.050 | 0.227 | 0.094 | 0.526 | 1 |
| *Decentralized Scheme with 2Nr WSP System* | 0.189 | 0.149 | 0.298 | 0.050 | 0.227 | 0.088 | 0.215 | 3 |
| *Centralized Scheme with Long Sea Outfall* | 0.189 | 0.149 | 0.298 | 0.050 | 0.227 | 0.088 | 0.260 | 2 |

### 9.4.6    Recommendation for Wastewater Treatment Train

From the Multi-criteria Analysis, it has been found out that Environmental Impacts, Land Acquisition, Simplicity of Operations & Maintenance and Net Present Value are the main determinants in the selection of Wastewater Management Scheme.

**On this basis, a Centralized Wastewater Treatment Plant at Uhuru Farm comprising of Waste Stabilization Ponds System is the most suitable Wastewater Management Scheme and is recommended for the Kilifi Sanitation Strategy.**

# 10.0  PRELIMINARY DESIGN OF SELECTED STRATEGY

## 10.1  Introduction

Kilifi Town currently lacks water-borne sanitation system to safeguard the health of its residents and the environment in general. The use of on-plot sanitation systems is prevalent.

Based on the TOR, a new sanitation system has been proposed for Kilifi Town i.e. Sewerage System and Wastewater Treatment Plant, to serve for a period of 20 years (2021 – 2040).

The selected sanitation system for Kilifi Town is a centralized scheme comprising of a Wastewater Treatment Plant and a collection and conveyance system within the extent of the study area.

Waste Stabilization Ponds (WSPs) System has been selected at the centralized Waste Water Treatment Plant, as the most appropriate treatment technology.

The main components of the proposed sanitation system include;

- Reticulation Sewerage Network connecting the Study area of Kilifi Town to the Wastewater Treatment Plant comprising Sewers (Trunk, Secondary and Tertiary Sewers) and Pumping Stations.
- Waste Water Treatment Plant (WSPs) comprising of Inlet Works, Anaerobic Ponds, Facultative Ponds, Maturation Ponds & Sludge Drying Beds, Administration Building with Laboratory and Store, Guard House and Grade 9 Staff Houses, and Associated Ancillary Works e.g. Access roads, water reticulation, drainage etc.

## 10.2  Sewerage System

### 10.2.1  Aerial Photographic surveys

During the Study, aerial photographic surveys were carried out over the entire study area of Kilifi Town which produced aerial images at 15 cm resolution. A Digital Terrain Model was developed and contours generated.

A Digital Topographical Map was developed showing all topographical features such as contours, buildings, structures, roads, railways, vegetation cover, surface water bodies and drains, telephone and power lines, permanent structures etc.

Ground truthing was done through ground survey using a hand-held GPS receivers and place names, landmarks, road names etc. were captured and overlaid on the Digital Topographical Map.

### 10.2.2  Sewer Alignments

Proper design and construction of new sewers in a developed urban area such as Kilifi Town involves identification and overcoming the unique challenges associated with working in a confined urban area.

In the selection of sewer alignment, preference has been given to the road reserves where adequate space for construction can be obtained with ease and where minimum interference with existing services such as Water Mains, Permanent Structures, Powerlines, etc. is expected. These locations also permit ease of access for future connections and maintenance. Minimum road crossings have been permitted along the proposed alignment at the necessary locations and preferably on roads without bitumen surfaces. At the road crossing, additional ground cover to the minimum requirement and concrete surrounds have been provided for pipe protection.

In circumstances where illegal structures were identified along the proposed sewer alignment and within the road reserves, provision for demolishing of such structures should be considered and associated costs included in the Bills of Quantities.

The existing wayleave is shared with other public utilities such as telephone and electricity lines, communication cables, etc. therefore, it will be crucial to liaise with the relevant utility providers at the commencement of the project to help in identification and relocation of affected utilities.

The Utility Providers shall also be required to provide details and locations of their utility network within the Project Area to reduce accidental damages. Provisional items should be allowed in the Bills of Quantities for any requisite works for relocation of the existing utilities.

### 10.2.3 Sewerage Network Analysis Model

The analysis of the proposed Sewerage Network for Kilifi Town has been carried out using a Hydraulic Network Model developed by the Consultant on a Microsoft Excel platform.

The benefit of adopting a simplistic and universally recognized platform such as Microsoft Excel for the development of the Sewerage Network Analysis Model is the ease with which the analysis can be carried out by manipulation of design parameters without compromising the reliability of the output / results.

Microsoft Excel is a spreadsheet application that allows one to manipulate, manage and analyse data thereby assisting in design by making use of the inbuilt tools and methodologies. The advantages of Excel are wide and varied. The main advantages of this platform include:

- **Easy availability and Familiarity;** Ms Excel is part of Microsoft office which comes with most Personal Computers. It is easily available and requires no purchase. It is easy to install and can be run by most people owing to its familiarity of its commands. It is an all in one programme and does not need the addition of analysis subsets or scripts.

- **Powerful analysis of large amounts of data -** Recent upgrades to the Excel spreadsheet enhance analyse of large amounts of data. With powerful filtering, sorting and search tools one can quickly and easily narrow down the criteria that will assist in the analysis. This is in addition to the inbuilt formulas and other analysis tools available on Ms Excel.

Details of the Model is given in the subsequent sub-sections;

### 10.2.3.1 Model Structure / Mathematical Basis

This Hydraulic Network Model is a deterministic model. A deterministic model is one whose outcomes are precisely determined through known relationships among states and events, without any room for random variation. In deterministic models, a given input will always produce the same output. In comparison, stochastic models use ranges of values for variables in the form of probability distributions.

This Model has been prepared to design for critical parameters required for a sewer to convey peak wastewater flow generated between sections (manholes) of the sewer profile by gravity based on Manning's equation and other known relationships as briefly described below. All the quantities are entered in the indicated SI units.

- *Manning Equation:* The Manning equation is widely used because of its simplicity. Although it is empirical, it gives an answer that is within the accuracy required, given the uncertainties associated with the flows generated (population projections, connected population, water consumption per person, etc.).

The formula is as follows:

$$V = \left( \frac{R^{0.67} \, x \, S^{0.5}}{n} \right)$$

Where:

| | | |
|---|---|---|
| V | = | velocity of flow, (m/s) |
| n | = | pipe roughness coefficient |
| R | = | hydraulic radius, (m) |
| S | = | slope of the pipeline, (m/m) |

- ***Discharge Formula***: Discharge through the pipe is determined by the equation;

$$Q = V \, x \, A$$

Where:

| | | |
|---|---|---|
| Q | = | Discharge (m³/s) |
| A | = | Sectional area of flow (m²) |

Other standard formulae such as for determining peak factors (See ***sub-section 3.2.4)*** and other geometric formulae have also been incorporated in the Model.

The assumptions of this Model relate to the formulas on whose basis it is formulated. For instance, it is assumed that the pipe roughness will remain constant for the entire lifespan of the sewer and a fixed roughness co-efficient adopted. A conservative value for 'n' has been adopted to take care of anticipated deterioration of the pipe smoothness.

The Model evaluates the adequacy of sewer diameter and slope for the peak flow while meeting the requirements spelt out under the design criteria such as sewage flowing approximately half-bore and resulting velocities within the permissible range.

A summary of the adopted design criteria for Kilifi Town Sewerage System as detailed in **Section 6.1** and summarised in **Table 10.1** below.

**Table 10.1: Adopted Design Criteria**

| Description | Adopted Criteria |
|---|---|
| Type of Sewerage System | Separate System |
| Sewage Contribution Factor | 80% of the water supplied to consumers |
| Infiltration | Infiltration Rate of 0.0025 l/s/ha |
| Splash Allowance | 5% of the wastewater flows |
| Peak Flow Factor | Based on Babbit and Harmon Formulas |
| Minimum Size of Sewer | 200mm Diameter |
| Hydraulic Design Criteria | Manning's Equation with the following design parameters:<br>• Pipe roughness coefficient, n          0.013<br>• Minimum velocity at peak flow          0.75 m/s<br>• Minimum velocity in exceptional circumstances   0.6 m/s<br>• Maximum velocity          3.0 m/s<br>• Maximum velocity in exceptional circumstances   6.0 m/s |
| Depth of Sewers | Depths range from 0.4m to 6.0m |
| Spacing of Manholes | 60m maximum spacing between manholes |
| Pipe Materials | • HDPE/ uPVC Pipes<br>• Socket and Spigot Concrete Pipes<br>• Steel Pipes with internal and external epoxy coating |

### 10.2.3.2 Model Parameters / Input Data Requirements

The input data required by the Model are as explained below and in the indicated units;

i. Manhole Details

The location and number of manholes for each sewer line are determined based on the guidelines indicated in *sub-section 6.1.7 – Manhole Spacing and Sizes.*

Each manhole is assigned a reference number and the chainage worked out from the last manhole. The manhole reference number, chainage and elevation are entered into the Model to determine length of sewer section being designed and the average ground slope.

ii. Population Equivalent (persons)

The population equivalent served by the sewer section is based on both the domestic wastewater contribution as well as that generated by the land-use activities within coverage area.

It has been assumed that the wastewater generated by one person is approximately *80 l/day.*

iii. Wastewater flow (l/s)

This refers to the total wastewater flow generated within a given sewer section. It depends on the number of connections on the sewer and the quantities discharged by each premise/ connection.

The wastewater flow adopted in the sewerage analysis is based on the projections of wastewater flows (*See Section 5.2*) which has been formulated from the findings of *Technical Note No. 2 - Waste Water Flow Predictions & Formulation of Sewerage Development Strategies - Kilifi Town*.

iv. Proposed Sewer Slope (m/m)

The contours generated within the Study Area from the Digital Terrain Model have been used to generate sewer line profiles.

The slope of the sewers is determined by the natural ground slope and levels of adjoining sewers. The sewer slope is modified in the Model accordingly to ensure the outputs meet the adopted design criteria especially self-cleansing velocity.

v. Proposed Pipe Diameter (mm)

The model calculates the internal pipe diameter required for the flow of sewage at full bore conditions between a sewer section. The resultant diameters are not standards sizes and the designer is required to enter a standard pipe diameter of a larger dimension.

## 10.2.4  Model Output

This Model analyses the gravity conveyance of the indicated wastewater flow for the sewer section at Peak Flow and Dry Weather Flow Conditions. The output is checked against the adopted design criteria.

Some of the main output of this Model include;

i. Proportion of sewage flow to the full-bore capacity (Qp/Qfull),

Sewers are usually designed to flow half full or at worst at three-quarter depth for big diameter pipes (diameter > 500mm). This is a critical output which determines the pipe diameter selection at a given slope.

ii.  Velocity of flow at full bore,

Velocity of flow in a sewer should not be less than 0.75 m/s to ensure attainment of self-cleansing conditions. On the other hand, the velocity should not exceed 3 m/s to reduce the abrasion effect of the contained solids.

Sewer Slope and diameter are adjusted accordingly to ensure velocity of sewage flow within this range.

### 10.2.5  Model Reliability

As earlier stated, this is a deterministic model whose output for similar conditions is constant. The formulas on whose basis it has been developed have been carefully entered and outputs run for known conditions.

Manual calculation of the sample condition (known situation with details of pipe diameter, slope, wastewater flow and the resulting velocities and fraction of sewage flow in the pipe) have been carried out to test the correctness of the outputs given by the Model.

The Model produces more precise outputs owing to the ability of Microsoft Excel to carry out computations to the highest accuracy possible.

### 10.2.6  Proposed Sewerage Network for Kilifi Town

Sewerage Analysis Model indicates that the range of diameter for the Sewers in Kilifi Town is 225 – 600 mm. The large diameter sewers of 600 mm are for the Trunk Sewers while the small diameter of 225 mm are to used for the secondary sewers.

A Layout Plan of the proposed Sewerage Network for Kilifi Town is given in **Figure 10.1** on **Page 10-6**.
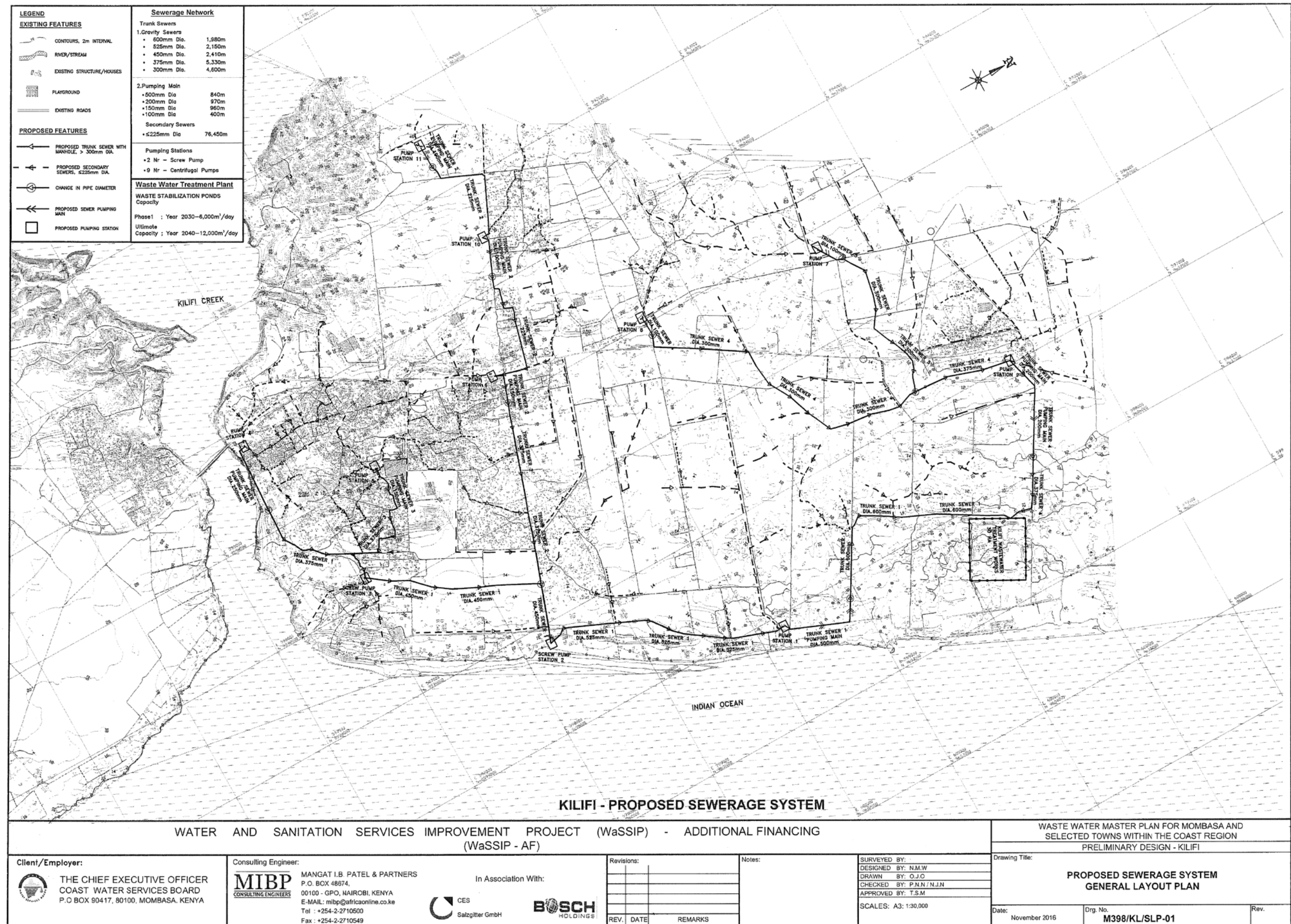
**Figure 10.1: Detailed Layout of the Sewerage System**

### 10.2.7　Phased Investment Schedule for Sewerage Network

The Proposed Wastewater Management Strategy for Kilifi Town entails construction of new Waste Water Treatment Plant and Sewerage System comprising of Pumping Stations, Trunk and Secondary Sewers.

The Sewerage Network proposed in the Wastewater Management Strategy has been studied with the aim of developing a Phased Investment Schedule.

Implementation phases of the Sewerage System has been formulated based on the following:
* Core Commercial Zone of Kilifi Town i.e. Central Business District
* Population Densities - High Density and Medium Density Residential Zones
* Land-Use Plan - Water Intensive Activities i.e. Industrial Zones

The two implementation phases formulated for Kilifi Town are described below;

### 10.2.7.1　Phase 1 (2021 – 2025) – Medium Term Plan

The Sewerage System classified under Phase 1 comprises of the following;
* Trunk Sewer connecting the core sewage generating zones to the proposed Waste Water Treatment Plant (WWTP) Site
* Secondary Sewers serving the core Central Business District (core Commercial Zones)
* Secondary Sewers serving Residential Zones with High Density and Medium Density Housing situated near the core CDB of Kilifi Town or adjacent to the WWTP
* Secondary Sewers serving Industrial Zones and other Water Intensive Land-Use Zones situated near the core CDB of Kilifi Town or adjacent to the WWTP

Summary of the Phase 1 Sewerage components is given in **Table 10.2** below.

**Table 10.2: Schedule of Sewerage System - Phase 1 (Medium-Term Plan: 2021 - 2025)**

| S/No | Sewer Line Reference No. | Dia (mm) | Length (m) | Pipe Material |
|------|--------------------------|----------|------------|---------------|
| 1 | Trunk Sewer - TS 1 | 600 | 1,980 | Concrete S&S |
| 2 | -Ditto- | 525 | 2,145 | Concrete S&S |
| 3 | -Ditto- | 450 | 2,405 | Concrete S&S |
| 4 | -Ditto- | 375 | 1,250 | Concrete S&S |
| 5 | Trunk Sewer - TS 2 | 375 | 1,705 | Concrete S&S |
| 6 | -Ditto- | 225 | 1,350 | Concrete S&S |
| 7 | Trunk Sewer - TS 3 | 375 | 705 | Concrete S&S |
| 8 | Pumping Main - TS 1 | 500 | 840 | Steel |
| 9 | -Ditto- | 250 | 680 | Steel |
| 10 | Pumping Main - TS 2 | 150 | 345 | Steel |
| 11 | Pumping Main - TS 3 | 150 | 585 | Steel |
| 12 | Secondary Sewers | 200 | 31,400 | uPVC |

### 10.2.7.2　Phase 2 (2026 - 2040) - Long Term Plan

The other parts of the study area which have Low Density Housing or lacking Water Intensive Land-Use activities (Industrial or Commercial Zones) but are earmarked for future utilization by these activities / settlements have been proposed for Sewerage Implementation under Long-Term Plan.

Summary of the Phase 2 Sewerage components is given in **Table 10.3** below.

**Table 10.3: Schedule of Sewerage System - Phase 2 (Long-Term Plan: 2026 - 2030)**

| S/No | Sewer Line Reference No. | Dia. (mm) | Length (m) | Pipe Material |
|------|--------------------------|-----------|------------|---------------|
| 1 | Trunk Sewer - TS 2 | 225 | 1000 | Concrete S&S |
| 2 | -Ditto- TS 4 | 375 | 1675 | Concrete S&S |
| 3 | -Ditto- TS 4 | 300 | 2978 | Concrete S&S |
| 5 | -Ditto- TS 5 | 300 | 1582 | Concrete S&S |
| 6 | Pumping Main - TS 2 | 100 | 600 | Steel |
| 7 | -Ditto- TS 4 | 100 | 160 | Steel |
| 8 | -Ditto- TS 4 | 200 | 1000 | Steel |
| 9 | -Ditto- TS 5 | 100 | 236 | Steel |
| 10 | Secondary Sewers | 225 | 44,700 | uPVC |

A Layout Plan of the proposed Sewerage Network for Kilifi Town showing each of the Sewerage Implementation Phases is given in **Figure 10.2** on **Page 10-9**.

Detailed calculation sheets for the proposed Trunk Sewers based on the Sewerage Network Analysis Model is given in **Volume 2: Master Plan Annexes – Section A1 (Trunk Sewers Design)**.

Layout Plans and Longitudinal Sections (Profiles) of the Trunk Sewers are given in **Volume 2: Master Plan Annexes – Section B (Engineering Drawings - Preliminary Design).**
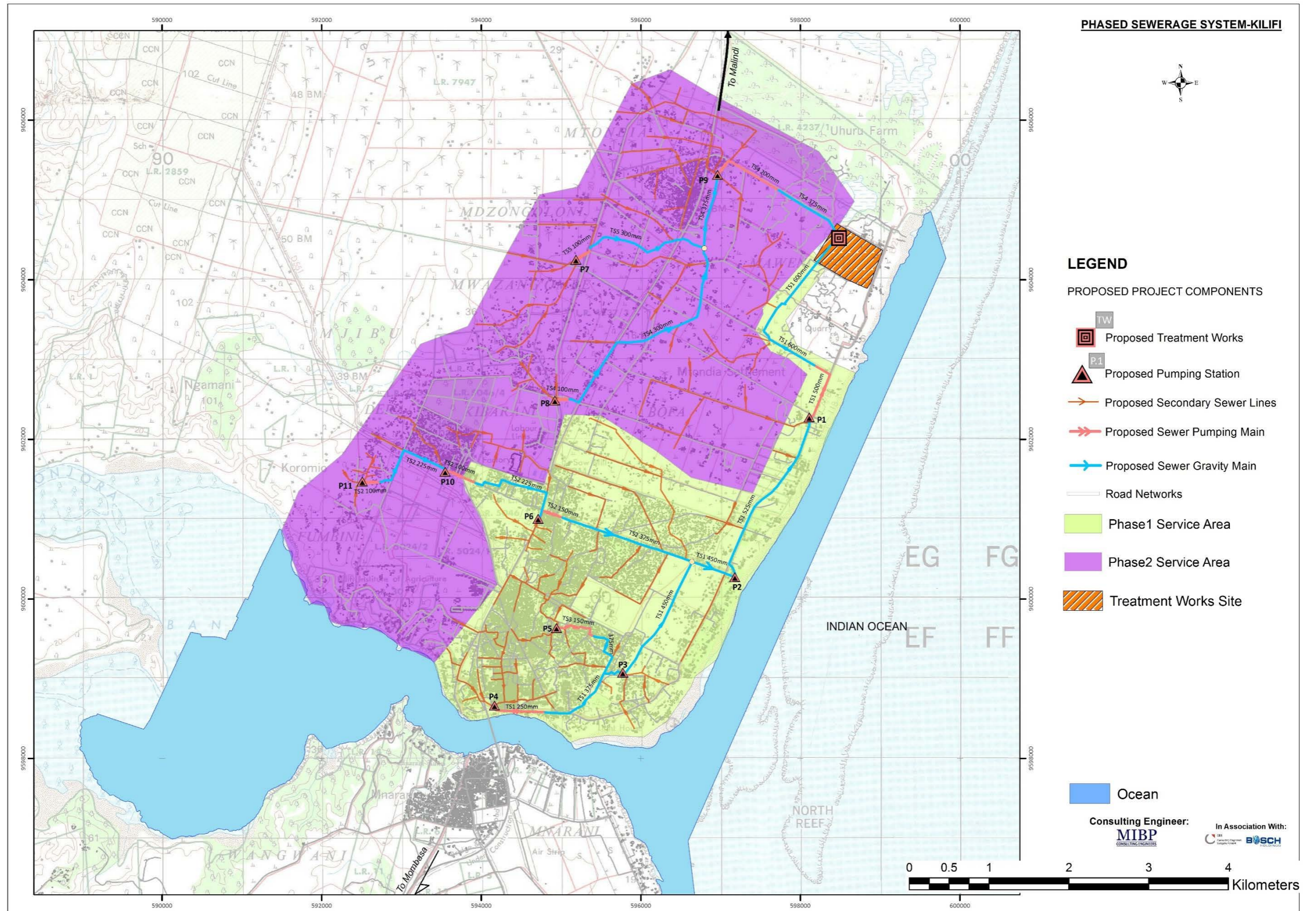
Figure 10.2: Layout Plan of the Phased Implementation of proposed Sewerage System

## 10.3    Pumping Stations

### 10.3.1   Siting of Pumping Stations

The pumping stations for the Sewerage System for Kilifi Town have been necessitated by low-lying points along the sewage conveyance routes. Some proposed stations lie close to residential properties and as such mitigation measures have been incorporated to ensure minimum hazard to public health and environment, especially during periods of electrical or mechanical failures.

A provision has been made at each proposed pumping station to have a screened overflow pipe, for use only during emergencies leading to a nearby stream where available. In other circumstances, an overflow pipe will be installed from the pump sump to a septic tank within the pump station compound. The County's exhauster vehicle can then be used to transport the sewage to the treatment facility while repairs are in progress.

### 10.3.2   Pumping Station Details

Two types of Pumping Stations have been proposed for the Sewerage System of Kilifi Town, namely;
- Screw Pump Stations (2Nr)
- Dry Well Station type (9 Nr) with separate Sewage Sump for temporary storage of conveyed sewage

Screw Pump Stations have been adopted in circumstances where lifting of sewage is required within heads less than 10m and where topography of the Sewerage alignment permits construction of such stations. Where Screw Pumps have been found to be unsuitable owing to topography or high boosting head requirement, Dry Well Station has been adopted.

In the Dry Well Station Type, the Sewage Sump is to be housed in the sub-structure of the Pumping Station while the Vertical Centrifugal Pump(s) and Motor(s) are to rest on the Super-structure including the control panels and the other associated equipment. Dry Well Stations have been adopted in lieu of Submersible pumps due to the ease of operation and maintenance of the pumps.

Each pumping station has been provided with a Preliminary Treatment Unit comprising of Screens and Grit Removal Structure. In addition, emergency overflow for use during pump failure has been incorporated from the Sewage Sump. A stand-by generator has also been provided in each Pumping Station.

It is proposed that the construction of Pumping Stations be carried out in one phase i.e. with floor area adequate to house the ultimate number of pump-sets and multiple sumps required for the ultimate flows. The pump and motor plinths are to be constructed in the initial phase to allow for the installation of the additional pumps at later phases.

### 10.3.3   Pump Configurations

The pumping capacity for each pump-set of Vertical Centrifugal Type has been designed compatible with the peak flows in the specific sewerage section. The percentage of stand-by unit in the proposed Pumping Stations vary depending on the economic analysis of the pump configuration. However, the reduction of the stand-by unit provision for the pumps in each Pumping Station at any implementation phase has been limited to 33%.

### 10.3.4  Schedule of Pumping Stations

The proposed Pumping Station for the Sewerage System have been designed based on the adopted criteria explained in *sub-sections 6.2.1 to 6.2.4*.

**Table 10.4** below gives a summary of details for the proposed Sewage Pumping Station.

**Table 10.4: Summary of Details for Sewage Pumping Stations**

| Pumping Station Ref. No. | Pumping Station Type | Pump Type | Details of Each Pump | | | Implementation Phase | |
|---|---|---|---|---|---|---|---|
| | | | Design Flow, Q (m³/h) | Pumping Head, H (m) | Power Requirement, P (kW) | 2021 - 2025 | 2026 - 2040 |
| P1 | Dry Well | Centrifugal | 712 | 21 | 57 | ✓ | ✓ |
| P2 | Screw | Screw | 593 | 5 | 10 | ✓ | ✓ |
| P3 | Screw | Screw | 352 | 5 | 6 | ✓ | ✓ |
| P4 | Dry Well | Centrifugal | 184 | 16 | 12 | ✓ | ✓ |
| P5 | Dry Well | Centrifugal | 85 | 27 | 9 | ✓ | ✓ |
| P6 | Dry Well | Centrifugal | 54 | 13 | 3 | ✓ | ✓ |
| P7 | Dry Well | Centrifugal | 33 | 17 | 2 | ✗ | ✓ |
| P8 | Dry Well | Centrifugal | 23 | 14 | 1 | ✗ | ✓ |
| P9 | Dry Well | Centrifugal | 128 | 15 | 8 | ✗ | ✓ |
| P10 | Dry Well | Centrifugal | 24 | 19 | 2 | ✗ | ✓ |
| P11 | Dry Well | Centrifugal | 24 | 12 | 1 | ✗ | ✓ |

**Figures 10.3** and **10.4** on **Pages 10-12** and **10-13** show the Layout Plan and Sections of a Screw Pump Station and Layout Plan and Sections of a Centrifugal Pump Station respectively.

**Figure 10.2** on **Page 10-9** shows the location of the proposed Pumping Stations in the Sewerage System.

Detailed calculation sheets for the Pumping Stations Components including the Sumps, Pumps and Motors are given in **Volume 2: Master Plan Annexes – Section A2 (Pumping Stations Design)**.

**NOTES:**

1. DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED

2. ALL EXPOSED CONCRETE EDGES TO HAVE A 25mm X 25mm CHAMFER

3. ALL INTERNAL PLASTRED BLOCKWORK OR CONCRETE TO BE PAINTED WITH APPROVED HIGHLY CHEMICAL RESISTANT EPOXY PAINT

4. CONCRETE WORKS: ALL REINFORCED CONCRETE TO BE CLASS 25/20 EXCEPT WHERE OTHERWISE SPECIFIED

5. ABBREVIATIONS

   R.C    - REINFORCED CONCRETE
   D.P.C - DAMP PROOF COURSE
   E.G.L - EXISTING GROUND LEVEL
   F.G.L - FINISHED GROUND LEVEL
   F.F.L - FINISHED FLOOR LEVEL
   P.C.C - PRECAST CONCRETE
   G.C.I -GALVANIZED CORRUGATED IRON

6. EDGES OF TREADS AND RISERS IN CONCRETE STAIRCASE TO BE PROTECTED WITH 40 X 40 X 3mm M.S. ANGLE FIXED WITH FISH TAIL LUGS EMBEDDED IN CONCRETE

7. FOR WINDOW AND DOOR SCHEDULE SEE STANDARD DRAWINGS

**Figure 10.3: Layout Plan and Sections of a Screw Pumping Station**

**Figure 10.4: Layout Plan and Sections of a Centrifugal Pumping Station**

## 10.4     Wastewater Treatment Plants

### 10.4.1    Treatment Technology Selection

A summary of the comparison of the various locally available treatment technologies has been presented on **Table 6.4** on **Page 6-17** to establish the context of comparison of the available technologies and the re-affirm the conclusions reached.

**Reference to the technologies comparison in Table 6.4 shows that the advantages of using Waste Stabilisation Ponds in Kenya over other technologies are so significant that they cannot be ignored.**  Their advantages can be summarised as follows:

- No mechanical and electrical equipment is needed, so no power is used in the process and little, or no, imported equipment is needed.
- The process takes place in simple lagoons and so the plant can be operated and maintained using only a small number of unskilled workers.
- Bacterial reduction and the removal of helminth eggs are superior to any other technology.
- Ability to absorb hydraulic and organic shock load - long retention times.
- Continuous sludge handling is not necessary. Facultative ponds need only be emptied every 15-20 years.  The sludge is stable and requires no special treatment.
- Construction of the ponds is very simple and so the cost of construction is generally lower than other plants. Besides, land can easily be reinstated at the end of the plant's useful life.
- Pond systems can easily be upgraded by installing anaerobic ponds prior to the facultative ponds or by converting the ponds into aerated lagoons.
- Ponds usually provide minimal negative environmental impact.
- The ponds can be designed to provide a final effluent usable for agricultural irrigation.

The main handicap of Waste Stabilisation Ponds (WSPs) is the large land area requirement. However, the advantages of waste stabilisation ponds are so overwhelming that, wherever feasible, ponds should be the first choice where sufficient suitable land is available.

**The high year-round ambient temperatures, availability of un-developed land within Kilifi and the simplicity of construction, render WSPs the most preferred wastewater treatment technology.**

### 10.4.2    Treatment Plant Location

A centralized Waste Water Treatment Plant is proposed at a dis-used quarry site at Uhuru Farm (Bofa/Maweni) (598574 m E, 9604413 m N). The location of the Waste Water Treatment Plant is shown on **Figure 10.1** and **10.2** on **Pages 10-6** and **10-9** respectively.

This site has been selected based on a check-list for site selection prepared in consideration of the pertinent physical, environmental and economic factors including the ease with which wastewater generated from the study area of Kilifi Town can be conveyed by minimal pumping to the site, land availability in this un-developed area and its safe distance away from built-up areas.

Based on the recommended treatment technology (WSPs) and the ultimate projected wastewater flows under realistic conditions of water supply and sewer connections *(Ultimate Design Capacity -12,000 m³/d; Refer to Section 5.2)*, the land required for the construction of the Waste Water Treatment Plant to serve the sanitation needs of Kilifi Town up to the ultimate horizon of year 2040 is approximately **30 Ha.**

The dis-used quarry is privately owned. It lies close to the Indian Ocean and the effluent can be discharged directly to the Indian Ocean through a short length of outlet sewer.

The site slopes gently towards the Indian Ocean with slopes that are sufficient to permit an adequate hydraulic profile through the ponds without incurring excessive earthworks.

The site is close to services such as water and electricity and is adjacent to Mombasa - Garissa Highway thus easily accessible.

### 10.4.3  Design Considerations

Many different methods have been proposed for the design of Waste Stabilization Ponds in hot climates. However, the most widely accepted standards and guidelines are those developed by G. V. Marais and D. D. Mara.

The design criteria and considerations that have been used for the design of WSPs for Kilifi Town is based on recommendations from D. D. Mara for use in Developing Countries.

The following is a summary of the main design criteria adopted in the design of the ponds:

### a)  Anaerobic Ponds

Anaerobic ponds are designed based on volumetric organic loading. The acceptable range of loadings is between 100 g/m³d and 300 g/m³d. The lower limit is to maintain anaerobic conditions while the upper limit is to control odour problems.

The loading is temperature dependent, as given in **Table 10.5** below:

**Table 10.5: Design Values of Volumetric BoD Loadings at Various Temperature**

| Temperature, T(°C) | Volumetric Loading, λv (g/m³d) |
|---|---|
| T < 10 °C | 100 |
| 10 °C < T > 20 °C | 20T-100 |
| T > 20 °C | 300 |

### b)  Facultative Ponds:

The design of a primary facultative pond is based upon the allowable organic surface loading that can be carried by the pond before failure (i.e. overloading) occurs.

The allowable surface loading in the primary pond is highly dependent upon the ambient temperature and it is common to use the mean temperature in the coldest month for design purposes.

The air temperatures in Kilifi are consistently moderately high throughout the year and a mean temperature in the coldest month of 24°C has been adopted. This mean temperature results to an allowable organic surface loading of 340 kg BOD/ha/day.

The depth of facultative ponds is based upon a compromise between being deep enough to prevent the emergence of weed growth, but without being too deep to allow anaerobic conditions to prevail. The ponds should also be deep enough to allow for a build-up of sludge over a period of years.

Depths are usually within 1.2 m and 2.0 m, with a commonly chosen depth of 1.5 metres.

### c) *Maturation Ponds:*

The primary function of maturation ponds is the reduction of bacterial concentrations. However, efficient removal of the eggs of parasitic worms is also achieved. Bacteria are removed by providing a hostile environment that is unsuitable for their survival and helminth ova are removed by sedimentation. BOD is also removed in maturation ponds, but at a much slower rate than in anaerobic and facultative ponds.

The removal of bacteria in maturation ponds follows the laws of first order kinetics in a completely mixed reactor as suggested by Marais. The bacterial reduction in a single pond is given by the equation:

$$Ne = Ni/(1+k_T\theta)$$

Where,       $Ne$       = number of FC/100ml in the effluent

$Ni$       = number of FC/100ml in the influent

$k_T$       = first order rate constant for FC removal, $d^{-1}$

$\theta$       = retention time, days

The rate constant is highly temperature dependent and for a temperature of 24 °C it has a value of 5.8 $day^{-1}$. The usual range of the faecal coliform concentration in raw sewage is $10^7$-$10^8$ faecal coliforms per 100 ml. A conservative design value of $5\times10^7$ FC per 100 ml has been adopted.

Maturation ponds are usually constructed as a series of ponds. The size and number of ponds provided is dependent on the required bacteriological quality of the final effluent. The minimum retention time for a maturation pond is three days.

Using the foregoing design values, the faecal coliform concentration in the effluent from a series of maturation ponds can be calculated and the number of ponds chosen to match the effluent quality requirements.

The adopted process design parameters for WSPs is given in **Table 10.6** below.

**Table 10.6: Adopted Process Design Parameters**

| Design Parameter | Unit | Value |
|---|---|---|
| **General:** | | |
| Raw Sewage BOD, Li | mg/l | 600 |
| Bacterial concentration of raw sewage | FC/100ml | $5\times10^7$ |
| Design Temperature | °C | 24.6 |
| First Order Rate Constant for FC Removal | days-1 | 5.8 |
| Embankment side slopes | 1 in 2.0 | |
| Freeboard allowance | m | 0.5 |
| **Anaerobic Ponds:** | | |
| Volumetric Loading, λv | $g/m^3d$ | 300 |
| Depth of Anaerobic Pond | m | 3.0 |
| Retention Period | Days | ≈ 3 |
| **Facultative Ponds:** | | |
| Organic Surface Loading, λs | kg/ha/day | 342 |
| Depth of Facultative Ponds | m | 1.5 |
| Retention time in Facultative Pond | Days | ≈ 10 |
| **Maturation Ponds:** | | |
| Depth of Maturation Ponds | m | 1.5 |
| Retention in each Maturation Pond | Days | ≈ 3 |

### 10.4.4  Waste Water Treatment Plant Details

Waste Stabilization Pond system has been designed to serve the sanitation needs of Kilifi Town up to the ultimate design horizon of Year 2040.

**Table 10.7** below shows a summary of details of the Wastewater Treatment Plant.

**Table 10.7: Details of Waste Water Treatment Plant – Year 2040**

| Design Parameter | Unit | Value |
|---|---|---|
| **Anaerobic Ponds:** | | |
| Number of Ponds | No. | 4 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions (Embankment) | m | 71 (L) x 40 (B) x 3 (D) |
| Free-Board (All Ponds) | m | 0.5 |
| Embankment Slope (All Ponds) | - | 1 in 2 |
| **Primary Facultative Ponds:** | | |
| Number of Ponds | No. | 4 |
| Retention Period (Each Pond) | Days | 8 |
| Dimensions (Embankment) | m | 236 (L) x 79 (B) x 1.5 (D) |
| **Secondary Facultative Ponds:** | | |
| Number of Ponds | No. | 4 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions (Embankment) | m | 77 (L) x 63 (B) x 1.5 (D) |
| **Maturation Ponds:** | | |
| Number of Ponds | No. | 8 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions | m | 75 (L) x 63 (B) x 1.5 (D) |
| **Sludge Drying Beds:** | | |
| Number of Beds | No. | 4 |
| Dimensions (Embankment) | m | 60 (L) x 35 (B) x 1.5 (D) |

The Site Layout Plan of the proposed Waste Water Treatment Plant is given in **Figure 10.5** on **Page 10-18**.

Typical details on the Inlet and Outlet Structures are also given in **Figure 10.6** on **Page 10-19.**

Detailed calculation sheets of the Wastewater Treatment Plants (Year 2030 and Year 2040) are given in **Volume 2: Master Plan Annexes – Section A3 (Wastewater Treatment Plant Design).**

STAFF HOUSES

GATE HOUSE

ADMINSTRATION BLOCK

SECONDARY FACULTATIVE POND No. 1 PHASE I

SECONDARY FACULTATIVE POND No. 3 PHASE II

PRIMARY FACULTATIVE POND No. 1 PHASE I

MATURATION POND No. 1.1 PHASE I

PRIMARY FACULTATIVE POND No. 2 PHASE II

MATURATION POND No. 3.1 PHASE II

MATURATION POND No. 1.2 PHASE I

MATURATION POND No. 3.2 PHASE II

SLUDGE DRYING BEDS 4No.

OUTFALL SEWER TO INDIAN OCEAN APPROXIMATE LENGTH 1Km

MATURATION POND No. 2.2 PHASE I

MATURATION POND No. 4.2 PHASE II

ANAEROBIC POND No. 1 PHASE I

PRIMARY FACULTATIVE POND No. 2 PHASE I

MATURATION POND No. 2.1 PHASE I

PRIMARY FACULTATIVE POND No. 4 PHASE II

MATURATION POND No. 4.1 PHASE II

ANAEROBIC POND No. 2 PHASE I

ANAEROBIC POND No. 3 PHASE II

SECONDARY FACULTATIVE POND No. 2 PHASE I

SECONDARY FACULTATIVE POND No. 4 PHASE II

ANAEROBIC POND No. 4 PHASE II

Area Required - 30 Hectares

**KILIFI WWTP, ULTIMATE CAPACITY 12,000m³/day**

| Description | Total Plan Area |
|---|---|
| Anaerobic Ponds, 4 Nr. | 11,300m² |
| Primary Facultative Ponds, 4 Nr. | 74,500m² |
| Secondary Facultative Ponds, 4 Nr. | 19,400m² |
| Maturation Pond, 8 Nr. | 74,500m³ |
| Sludge drying Beds, 4Nr. | 8,300m³ |

**LEGEND**

- PHASE I PONDS
- PHASE II PONDS
- 5m WIDE TARMAC PAVED ROAD
- CHAIN LINK FENCE
- SEWER LINE WITH MANHOLES
- CHAIN LINK FENCE
- STORM WATER DRAIN
- SEWER LINE WITH CHAMBERS
- PROPOSED BUILDINGS
- CONTOURS AT 2m INTERVALS

WATER AND SANITATION SERVICES IMPROVEMENT PROJECT (WaSSIP) - ADDITIONAL FINANCING (WaSSIP - AF)

Client/Employer:

THE CHIEF EXECUTIVE OFFICER COAST WATER SERVICES BOARD
P.O BOX 90417, 80100, MOMBASA, KENYA

Consulting Engineer:

MIBP CONSULTING ENGINEERS

MANGAT I.B. PATEL & PARTNERS
P.O. BOX 48674,
00100 - GPO, NAIROBI, KENYA
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In Association With:

CES Salzgitter GmbH

BOSCH HOLDINGS

Revisions:

Notes:

| SURVEYED BY: | N.M.M. |
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| DRAWN BY: | A.M. |
| CHECKED BY: | N.J.N |
| APPROVED BY: | R.S.R |

REV. DATE REMARKS

SCALES: A1:   A3:   1:2500

WASTE WATER MASTER PLAN FOR MOMBASA AND SELECTED TOWNS WITHIN THE COAST REGION

PRELIMINARY DESIGN - KILIFI TOWN

Drawing Title:

PROPOSED WASTEWATER TREATMENT WORKS LAYOUT PLAN

Date: March 2017   Drg. No. M398/KI/TW/SLP/01   Rev.

**Figure 10.5: Layout Plan of the Proposed Waste Water Treatment Plant**

**Figure 10.6: Typical Inlet and Outlet Structures for the Ponds**

### 10.4.5  Phased Investment Schedule for Waste Water Treatment Plant

Since the wastewater generated within the study area is expected to increase with the population and more land-use utilization, it is prudent to phase the implementation of the Waste Water Treatment Plant i.e.  Medium-Term and Long-Term Plan.

### 10.4.5.1  Medium-Term Plan (2021 - 2025)

Medium Term Plan includes construction of the Waste Water Treatment Plant (WWTP) to serve the sanitation needs of Kilifi Town up to year 2025. To provide for additional capacity during the implementation of the second phase (Long-Term Plan; 2026 - 2040), the WWTP has been designed to handle the projected wastewater generated up to year 2028.

From **Figure 2.3** on **Page 2-7,** the projected wastewater flow for year 2028 is approximately 6,000 m³/d, based on realistic conditions of water supply and sewer connections.

Details of Wastewater Treatment Plant designed for implementation in the Medium-Term Plan is given in **Table 10.8** below**.**

**Table 10.8: Details of Waste Water Treatment Plant: Medium-Term Plan**

| Design Parameter | Unit | Value |
|---|---|---|
| **Anaerobic Ponds:** | | |
| Number of Ponds | No. | 2 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions (Embankment) | m | 71 (L) x 40 (B) x 3 (D) |
| Free-Board (All Ponds) | m | 0.5 |
| Embankment Slope (All Ponds) | - | 1 in 2 |
| **Primary Facultative Ponds:** | | |
| Number of Ponds | No. | 2 |
| Retention Period (Each Pond) | Days | 8 |
| Dimensions (Embankment) | m | 236 (L) x 79 (B) x 1.5 (D) |
| **Secondary Facultative Ponds:** | | |
| Number of Ponds | No. | 2 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions (Embankment) | m | 77 (L) x 63 (B) x 1.5 (D) |
| **Maturation Ponds:** | | |
| Number of Ponds | No. | 4 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions | m | 75 (L) x 63 (B) x 1.5 (D) |
| **Sludge Drying Beds:** | | |
| Number of Beds | No. | 2 |
| Dimensions (Embankment) | m | 60 (L) x 35 (B) x 1.5 (D) |

### 10.4.5.2  Long-Term Plan (2026 -2040)

The second phase of the implementation schedule involves construction of the additional units to augment the capacity of the Waste Water Treatment Plant to handle the increased ultimate wastewater generation of year 2040 i.e. 12,000 m³/d, based on realistic conditions of water supply and sewer connections.

Details of the Waste Water Treatment Units required for Long-Term Plan has been given in **Table 10.9** on **Page 10-20.**

The details of the second Implementation Phase which is meant to provide the additional capacity of 6,000 m³/d at the Waste Water Treatment Plant is given in **Table 10.9** below.

**Table 10.9: Details of Additional Units at the Waste Water Treatment Plant: Long-Term Plan**

| Design Parameter | Unit | Value |
|---|---|---|
| **Anaerobic Ponds:** | | |
| Number of Ponds | No. | 2 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions (Embankment) | m | 71 (L) x 40 (B) x 3 (D) |
| Free-Board (All Ponds) | m | 0.5 |
| Embankment Slope (All Ponds) | - | 1 in 2 |
| **Primary Facultative Ponds:** | | |
| Number of Ponds | No. | 2 |
| Retention Period (Each Pond) | Days | 8 |
| Dimensions (Embankment) | m | 236 (L) x 79 (B) x 1.5 (D) |
| **Secondary Facultative Ponds:** | | |
| Number of Ponds | No. | 2 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions (Embankment) | m | 77 (L) x 63 (B) x 1.5 (D) |
| **Maturation Ponds:** | | |
| Number of Ponds | No. | 4 |
| Retention Period (Each Pond) | Days | 2 |
| Dimensions | m | 75 (L) x 63 (B) x 1.5 (D) |
| **Sludge Drying Beds:** | | |
| Number of Beds | No. | 2 |
| Dimensions (Embankment) | m | 60 (L) x 35 (B) x 1.5 (D) |

## 10.5 Phased Implementation Costs

### 10.5.1 Land Acquisition Cost

Approximately 30Ha of land is required for the construction of Wastewater Treatment Plant and Pumping Stations in Kilifi Town to serve the sanitation needs up to Year 2040. The estimated cost of land acquisition based on a unit rate of Kshs. 5,000,000 per Hectares is **Kshs. 150,000,000.**

The requisite parcels of land need to be acquired in the Medium-Term Plan.

### 10.5.2   Implementation Costs for Phased Sewerage System

The estimated costs for each of the Implementation Phases is given in **Tables 10.10** and **10.11** below;

**Table 10.10: Costs for Phase 1 Sewerage System: Medium-Term Plan**

| S/No | Item Description | Cost (Kshs) | Costs (USD) |
|---|---|---|---|
| 1 | Trunk Sewers | 159,932,919 | 1,552,747 |
| 2 | Secondary Sewers | 452,586,093 | 4,394,040 |
| 3 | Pumping Mains | 32,376,429 | 314,334 |
| 4 | Pumping Stations | 26,700,000 | 259,223 |
| | **Sub-Total 1** | **671,595,441** | **6,520,344** |
| | Add 7.5% of Sub-Total 1 for Preliminary and General | 50,369,658 | 489,026 |
| | **Sub-Total 2** | **721,965,099** | **7,009,370** |
| | Add 10% of Sub-Total 2 for Physical Contingencies | 72,196,510 | 700,937 |
| | **Sub-Total 3** | **794,161,609** | **7,710,307** |
| | Add 10% of Sub-Total 3 for Price Contingencies | 79,416,161 | 771,031 |
| | **Sub-Total 4** | **873,577,770** | **8,481,338** |
| | Add 5% of Sub-Total 4 for Consultancy | 43,678,888 | 424,067 |
| | **GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES** | **917,256,658** | **8,905,404** |

**Table 10.11: Costs for Phase 2 Sewerage System: Long-Term Plan**

| S/No | Item Description | Cost (Kshs) | Costs (USD) |
|---|---|---|---|
| 1 | Trunk Sewers | 94,986,291 | 922,197 |
| 2 | Secondary Sewers | 645,863,993 | 6,270,524 |
| 3 | Pumping Mains | 23,010,870 | 223,407 |
| 4 | Pumping Stations | 22,500,000 | 218,447 |
| | **Sub-Total 1** | **786,361,154** | **7,634,574** |
| | Add 7.5% of Sub-Total 1 for Preliminary and General | 58,977,087 | 572,593 |
| | **Sub-Total 2** | **845,338,240** | **8,207,167** |
| | Add 10% of Sub-Total 2 for Physical Contingencies | 84,533,824 | 820,717 |
| | **Sub-Total 3** | **929,872,064** | **9,027,884** |
| | Add 10% of Sub-Total 3 for Price Contingencies | 92,987,206 | 902,788 |
| | **Sub-Total 4** | **1,022,859,270** | **9,930,673** |
| | Add 5% of Sub-Total 4 for Consultancy | 51,142,964 | 496,534 |
| | **GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES** | **1,074,002,234** | **10,427,206** |

### 10.5.3    Implementation Costs for Phased Investment on Wastewater Treatment Plant

The estimated implementation costs for the Wastewater Treatment Plant to serve both the Medium-Term (Year 2021 – 2025) and Long-Term (2026 – 2040) sanitation needs of Kilifi Town is summarised in **Tables 10.12** and **10.13** below.

**Table 10.12: Costs for Phase 1 Wastewater Treatment Plant: Medium-Term Plan**

| S/No. | Components | No. | Cost (Kshs) | Costs (USD) |
|---|---|---|---|---|
| 1 | Inlet Works | 1 | 26,558,508 | 257,850 |
| 2 | Anaerobic Ponds | 2 | 138,472,438 | 1,344,393 |
| 3 | Primary Facultative Ponds | 2 | 133,343,829 | 1,294,600 |
| 4 | Secondary Facultative Ponds | 2 | 30,771,653 | 298,754 |
| 5 | Maturation Ponds | 4 | 61,543,306 | 597,508 |
| 6 | Sludge Drying Beds | 2 | 41,028,870 | 398,339 |
| 7 | Administration Building | 1 | 8,850,000 | 85,922 |
| 8 | Staff Houses | 2 | 4,500,000 | 43,689 |
| 9 | Site and Ancillary Works | - | 94,531,865 | 917,785 |
| | **Sub-Total 1** | | **539,600,469** | **5,238,840** |
| | Add 7.5% of Sub-Total 1 for Preliminary and General | | 40,470,035 | 392,913 |
| | **Sub-Total 2** | | **580,070,504** | **5,631,752** |
| | Add 10% of Sub-Total 2 for Physical Contingencies | | 58,007,050 | 563,175 |
| | **Sub-Total 3** | | **638,077,554** | **6,194,928** |
| | Add 10% of Sub-Total 3 for Price Contingencies | | 63,807,755 | 619,493 |
| | **Sub-Total 4** | | **701,885,310** | **6,814,420** |
| | Add 5% of Sub-Total 4 for Consultancy | | 35,094,265 | 340,721 |
| | **GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES** | | **736,979,575** | **7,155,142** |

**Table 10.13: Costs for Phase 2 Wastewater Treatment Plant: Long-Term Plan**

| S/No. | Components | No. | Cost (Kshs) | Costs (USD) |
|---|---|---|---|---|
| 1 | Anaerobic Ponds | 2 | 113,773,949 | 1,104,601 |
| 2 | Primary Facultative Ponds | 2 | 109,560,099 | 1,063,690 |
| 3 | Secondary Facultative Ponds | 2 | 25,283,100 | 245,467 |
| 4 | Maturation Ponds | 4 | 50,566,200 | 490,934 |
| 5 | Sludge Drying Bed | 2 | 33,710,800 | 327,289 |
| 6 | Site and Ancillary Works | - | 32,633,128 | 316,826 |
| | **Sub-Total 1** | | **365,527,276** | **3,548,809** |
| | Add 7.5% of Sub-Total 1 for Preliminary and General | | 27,414,546 | 266,161 |
| | **Sub-Total 2** | | **392,941,821** | **3,814,969** |
| | Add 10% of Sub-Total 2 for Physical Contingencies | | 39,294,182 | 381,497 |
| | **Sub-Total 3** | | **432,236,003** | **4,196,466** |
| | Add 10% of Sub-Total 3 for Price Contingencies | | 43,223,600 | 419,647 |
| | **Sub-Total 4** | | **475,459,604** | **4,616,113** |
| | Add 5% of Sub-Total 4 for Consultancy | | 23,772,980 | 230,806 |
| | **GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES** | | **499,232,584** | **4,846,918** |

### 10.5.4  Summary of Phased Investment Costs

A summary of the Phased Investment cost for Kilifi Wastewater Management Scheme is given in **Tables 10.14** and **Table 10.15** below;

**Table 10.14: Costs for Medium-Term Plan (Year 2020 – 2025)**

| S/No. | Component | Cost (Kshs) | Costs (USD) |
|---|---|---|---|
| 1 | Land Acquisition | 150,000,000 | 1,456,311 |
| 2 | Sewerage System | 917,256,658 | 8,905,404 |
| 3 | Wastewater Treatment Plant | 736,979,575 | 7,155,142 |
|  | Total | **1,804,236,233** | **17,516,857** |

**Table 10.15: Costs for Long-Term Plan (Year 2026 – 2040)**

| S/No. | Component | Cost (Kshs) | Costs (USD) |
|---|---|---|---|
| 1 | Sewerage System | 1,074,002,234 | 10427,206 |
| 2 | Wastewater Treatment Plant | 499,232,584 | 4,846,918 |
|  | Total | **1,573,234,818** | **15,274,124** |

## 10.6   Wastewater Reuse

### 10.6.1   Justification for Wastewater Reuse

The Proposed Wastewater Treatment Plant (WWTP) for Kilifi Town comprising of Waste Stabilization Ponds System (ultimate design capacity of 12,000 m$^3$/day) is to be sited at at a dis-used quarry at Uhuru Farm (Bofa/Maweni area).

Owing to the current suppressed water supply conditions, limited resources for development of new water resources and expansion of water distribution network as well as the cost to be incurred in the construction and running of the Wastewater Treatment Plant (WWTP) in Kilifi Town, it is prudent to consider reusing treated effluent from the WWTP.

As practiced in most developing countries, large quantities of treated effluent (wastewater) can be reused for both potable and non-potable uses such as agriculture, aquifer recharge, industries, residences, etc. Its thus important to evaluate the feasibility of reusing wastewater in Kilifi Town.

### 10.6.2   Types of Wastewater Reuse Applications

The main wastewater reuse applications are described below;

#### 10.6.2.1 Agricultural Reuse

The Coastal region of Kenya is an important agro-ecological zone and a water scarcity area. The climatic conditions are of hot lowland humid tropics. The crops commonly cultivated in Kilifi include; Mangoes, Cashew nuts, Coconuts, Copra, Cotton, Vegetables, Citrus Trees, Bananas, Macadamia Nuts, etc.

However, commercial farming is not viable mainly because of water scarcity, unproductive soils and unfavourable terrains. With wastewater reuse and its associated nutrient benefits, it is expected that increased productivity of agriculture can be realized.

#### 10.6.2.2 Industrial Reuse

Industries accounts for a significant fraction of water use for a Water Supply Project. The exact amount of industrial water use depends on the use, scale of industry and type of processing use (whether water intensive or not).

For industries with water-intensive processes, suppressed water supply can limit the productivity or increase operation costs if the target production is to be attained. Over the past few years, industries have embraced wastewater reuse for purposes ranging from process water, boiler feed water, cooling processes water, etc. Thus, reuse of treated wastewater is an alternative source of non-potable industrial water applications.

#### 10.6.2.3 Urban Reuse

A large percentage of public water supplied to premises constitute of non-potable water uses which does not require the potable water requirements. To reduce the cost incurred in treating bulk water for public supply, dual distribution systems comprising of separate pipes for potable water and non-potable water have been utilized in some developed countries. This system contributes to the conservation of limited water resources.

Wastewater treated by secondary processes and followed by sand filtration and disinfection is commonly used for non-potable purposes such as car washing, garden watering, and firefighting. These urban applications are not cost effective owing to the inherent high Capital Expenditures (CAPEX) and Operation & Maintenance Expenditures (OPEX) which would translate to exorbitant tariffs and consequently reduce the affordability of urban wastewater reuse.

### 10.6.2.4 Environmental Reuse

Environmental reuse includes natural/artificial streams augmentation, fountains, recreational features, wetlands and ponds. With increased population and urbanization in Kilifi, green spaces which serve as natural conservancies and groundwater recharge points are getting depleted. The drastic reduction in green spaces and conservancies has resulted in reduced infiltration to recharge groundwater resources and increased flooding.

It is thus necessary to explore possibilities of environmental wastewater reuse for Kilifi Town. Compared to conventional surface water storage, aquifer recharge has negligible evaporation, little secondary contamination by animals and no algal blooming. Aquifer recharge is also less costly because no pipeline construction is required. In the Kenyan Coastal region, wastewater reuse for aquifer recharge will protect groundwater from saltwater intrusion by barrier formation.

A figure showing three common types of aquifer recharge is given in **Figure 10.7** below.
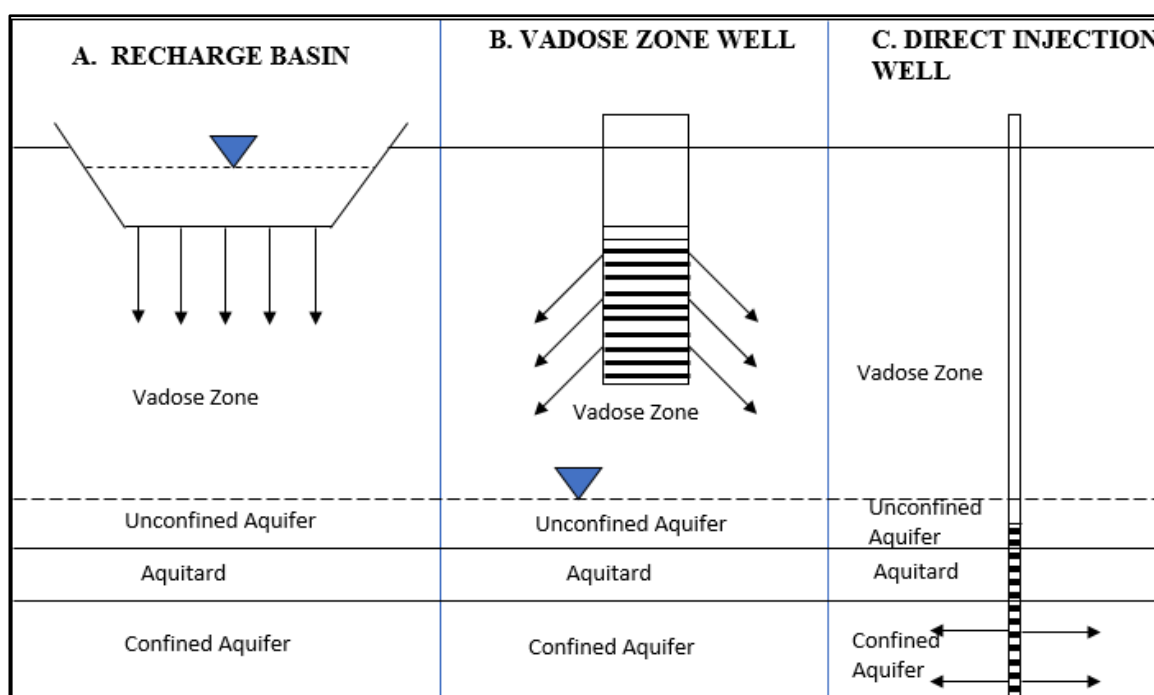


**Figure 10.7: Types of Aquifer Recharge**

The aquifer recharge types are briefly explained below:

a) **Recharge Basin**

This requires a wide area with permeable soil, an unconfined aquifer with transmissivity, and an unsaturated (or vadose) zone without restricting layers. With this system, the vadose zone and aquifer work as natural filters and remove suspended solids, organic substances, bacteria, viruses and other microorganisms. In addition, reduction of nitrogen, phosphorus and heavy metals can also be achieved. This process is called soil-aquifer treatment.

b) **Direct Injection**

This recharge type can access deeper aquifers through an injection well. Direct injection is utilized when aquifers are deep or separated from the surface by an impermeable layer. This method requires less land than the recharge basin methods, but it costs more to construct and maintain.

A well-wall is susceptible to clogging by suspended solids, biological activity or chemical impurities. In this method, the soil aquifer treatment effect is not observed. The method requires advanced pre-treatment of applied water, including sufficient disinfection. Without treatment, the injected wastewater may pollute the aquifer.

### c) Vadose Zone Injection

This is an emerging technology that provides some of the advantages of both recharge basins and direct injection wells. It is used when a permeable layer is unavailable at a shallow depth, and a recharge well has relatively large diameter.

Aquifer recharge is important in Kilifi for the prevention of groundwater level decline and preservation of the groundwater resource for future use.

### 10.6.3 Fit-for-Purpose

Based on the adopted wastewater treatment technology and level of treatment process developed, the wastewater effluent characteristics will determine the type of reuse application that is fit-for-purpose. While reuse of treated wastewater poses additional financial, technical and institutional challenges, a range of treatment options are available such that any level of water quality required by any reuse application can be achieved.

An illustration of how the level of water treatment affect the water quality is given in **Figure 10.8** below.
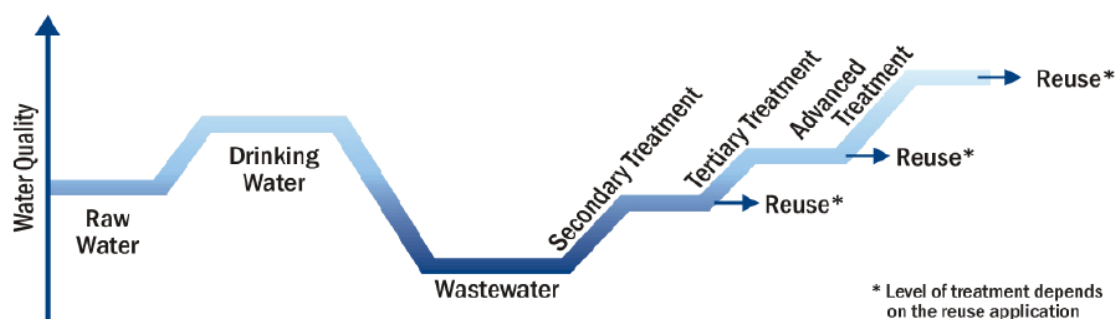


**Figure 10.8: Level of wastewater quality**

To optimize wastewater reuse and cost reduction potential, appropriate technology and its availability should be selected.

The types of reuse technology appropriate for increasing levels of wastewater treatment are summarized in **Table 10.16** on **Page 10-27**

**Table 10.16: Types of Reuse appropriate for Increasing Levels of Treatment**

| Description | Increasing Levels of Treatment | | | |
| | Primary | Secondary | Filtration and Disinfection | Advanced |
|---|---|---|---|---|
| Level of Treatment | Sedimentation | Biological oxidation and disinfection | Chemical coagulation, biological or chemical nutrient removal, filtration, and disinfection | Activated carbon, reverse osmosis, advanced oxidation processes, soil aquifer treatment, etc. |
| End Use | No Uses Recommended | Surface irrigation of orchards and vineyards | Landscape and golf course irrigation | Indirect potable reuse including groundwater recharge of potable aquifer and surface water reservoir augmentation and potable reuse |
| | | Non-food crop irrigation | Toilet flushing | |
| | | Restricted landscape impoundments | Vehicle washing | |
| | | Groundwater recharge of non-potable aquifer | Food crop irrigation | |
| | | Wetlands, wildlife habitat, stream augmentation | Unrestricted recreational impoundment | |
| | | Industrial cooling processes | Industrial systems | |
| Human Exposure | Increasing Acceptable Levels of Human Exposure | | | |
| Cost | Increasing Levels of Cost | | | |

The wastewater treatment technology selected for Kilifi Town is the Waste Stabilization Ponds System (WSPs). The WSPs comprises of the following functional units;

a. Inlet works
b. Anaerobic Ponds
c. Facultative Ponds
d. Maturation Ponds
e. Sludge Drying Beds
f. Outfall sewer (For discharge to receiving environment)

These treatment processes are predominantly physio-biological and entails wastewater treatment up to the secondary level.

Potential wastewater reuse for effluent treated up to secondary treatment level as shown in **Table 10.16** above include;

- Surface irrigation of orchards and vineyards
- Non-food crop irrigation
- Wetlands, wildlife habitat, stream augmentation
- Restricted landscape impoundments
- Groundwater recharge of non-potable aquifer
- Industrial cooling processes

### 10.6.4  Selection of Wastewater Reuse Applications

In the selection of the reuse application, it is important to consider the Land-use Maps to guide on the proposed activities and their land allocations. For financial considerations, only those land-use activities which are within proximity to the Wastewater Treatment Plant are to be considered for wastewater reuse.

A layout plan showing the proposed land use for Kilifi Town is given in **Figure 3.3** on **Page 3-9**.

Based on the proposed Land-Use Plan and the Level of Wastewater treatment proposed at the Wastewater Treatment Plant, only three main wastewater reuse applications can be considered in Kilifi Town, i.e., Agricultural, Industrial and Environmental

Details of proposed area allocated for Agricultural, Industrial and Environmental land uses in the year 2040 for Kilifi Town are given in **Table 10.17** below.

**Table 10.17: Details of Land for Re-use Application (Year 2040)**

|   | Land Use | Area Allocated (ha) |
|---|---|---|
| 1. | Agricultural | 4,004 |
| 2. | Industrial | 26 |
| 3. | Environmental | 3 |

Based on **Table 10.17** above, the following conclusion can be drawn:

- Agriculture is one of the dominant economic activities in Kilifi. It promotes growth of the Town and creates employment opportunities. However, the farming practice is rain-fed. Agricultural productivity can be greatly enhanced if farmers embrace wastewater reuse practice which would utilize the treated wastewater to be available throughout the year.
- The proposed area for industrial zones are sparse located with approximate distance from proposed WWTP of 6 Km and thus, wastewater reuse for industrial purposes will be uneconomical considering the conveyance requirements. Besides, high concentration of Total Dissolved Solids (TDS) of wastewater treated by Waste Stabilization Ponds (WSPs) disqualifies the industrial cooling reuse applications based on the possibilities of scale formation and associated blockage effects on the conveyance conduits. Further, the high-water quality requirements for industrial processes render the effluents from WSPs unfit for other industrial applications such as for food processing, cleaning, etc.
- The total area allocated for environmental purposes, specifically recreation, is relatively small compared to available wastewater for reuse. In addition, the recreational areas are scattered within the Town and would make conveyance expensive. In this respect, wastewater reuse for environmental purposes will not be economical in Kilifi.

**In conclusion, agricultural application is the most suitable for wastewater reuse considering the level of wastewater treatment at the Wastewater Stabilization Ponds and the predominant practice of agriculture in Kilifi.**

Assuming a coverage within 4km radius from the proposed WWTP site as an economic distance with relatively small head difference, approximately **1,880 Ha** of land is earmarked for agricultural use (See **Figure 10.9** on **Page 10-31**).

The volumetric water requirement for agricultural wastewater reuse is determined by the cash crop cultivated among other factors.

A schedule of cash crops cultivated in Kilifi and their water requirements is given in **Table 10.18** below.

**Table 10.18: Water requirements for Cash Crops grown**

|   | Cash Crop | Water requirement (m³/ha/day) |
|---|---|---|
| 1. | Mango Trees | 55 |
| 2. | Coconuts | 360 |
| 3. | Cashew nuts | 1,545 |
| 4. | Citrus | 35 |
| 5. | Cotton | 55 |
| 6. | Vegetable | 5 |
| 7. | Copra | 80 |
| 8. | Macadamia nuts. | 20 |
| 9. | Lawn Grass | 175 |

It has been established during the visits and investigations of the Study Area that Mango is the predominant cash crop cultivated in the area.

The establish the potential irrigable land in Kilifi, the following assumptions have been made;

    a. The crop to be cultivated on the irrigated land is mango; with water requirement of 55 m³/ha/day

    b. Only 80% of the treated wastewater will be available for agricultural reuse in consideration of the losses due to evaporation, seepage and transmission losses

    c. 40% of the farmers within the area proposed for agricultural irrigation by treated wastewater reuse will embrace the practice. This will only be attainable if aggressive public education and awareness campaigns are conducted on proper handling of the wastewater

Thus, Net Water Available for agricultural reuse = 0.8 x 12,000 m³/day

$$= 9,600 \text{ m}^3/\text{day}$$

The gross total area which can be put under irrigation considering only the 40% utilization is given by;

Gross Total Area, $A_G$      $= \dfrac{9{,}600 \; m3/d}{55 \; m3/ha/d \; x \; 0.4}$

         = **436 Ha**

Therefore, the available wastewater for agricultural reuse application is adequate for farms with total coverage of approximately **440 ha**.

A layout plan showing the proposed land which can be irrigated with wastewater reuse (440 Ha) and the coverage of agricultural land within 4 km radius from the proposed T-works (1,880 Ha) is shown in **Figure 10.9** on **Page 10-31.**

### 10.6.5 Conveyance and Storage System of wastewater for Reuse

To cover the potential irrigable area of **440 Ha**, the treated water will be conveyed from the WWTP site at an elevation of 2 m asl to a Storage Facility at an elevation of 20 m asl by means of pumping. The distance between these points is approximately 4.0 km.

The Conveyance and Storage system shall comprise of the following components;

    a) Pumping Station at the WWTP

- Pump Discharge - 1,000 m³/hr
- Pumping Head - 58 m
- Power requirement - 227 kW

    b) Rising Main

- Pipe Material - Steel pipe
- Diameter - 450 mm
- Length - 4.5 Km

    c) Lined Pond for storage

- 1.5m deep well compacted Earth Pond (Capacity 9,500 m³)
- Proposed site; co-ordinates 595442 m E, 9605060 N
- Land requirement - **1.7 ha**

    d) Overflow Sewer & Manholes

- To connect Lined Pond to Indian Ocean
- Pipe Details - 450mm diameter concrete pipe
- Length - approximately 4.5 Km

A layout plan showing Conveyance and Storage system is shown on **Figure 10.9** on **Page 10-31.**

KILIFI TOWN LANDUSE FOR AGRICULTURAL WASTE WATER RE-USE SYSTEM

N

**LEGEND**
- Discharge Point
- Pumping Station
- Rising Main
- Overflow Gravity Main
- Storage Pond
- Fence
- Proposed T.Works Site
- 4 Km Buffer Zone
- Allocated Agricultural Land(1,880Ha)
- Proposed Agricultural Land for Waste Warer Re_Use(440Ha)
- Ocean

**Kilifi Landuse**
- Agricultural
- Commercial
- Educational
- High Density Residential
- Industrial
- Low Density Residential
- Mangroves
- Medium Density Residential
- Open Space
- Open Spaces
- Public Purpose
- Recreational
- Transportational

Scale; 1:32,000

Consulting Engineer:
In Association With:
MIBP CONSULTING ENGINEERS
CES Salzgitter Gmbh
BOSCH HOLDINGS

Storage Pond
Capacity = 9,500 m$^3$
Area = 1.7 Ha
Elevation = 20m

Rising Main(Steel)
L = 4.5 Km
$\phi$ = 450 mm

$Q_{DWF}$ = 12,000 m$^3$/ day
Hp = 58 m
Elevation = 2m

$Q_{DWF}$ = 12,000 m$^3$/ day
Area = 30Ha
WASTE STABILIZATION PONDS

Effluent Outfall(Concrete)
L = 4.5 Km
$\phi$ = 450 mm

INDIAN OCEAN

4 Km

**Figure 10.9: Layout Plan of the Conveyance and Storage System for Agricultural Wastewater Reuse – Kilifi**

### 10.6.6  Implementation Costs for the Agricultural Wastewater Reuse Scheme

### 10.6.6.1  Capital Cost

The Capital Costs for the Agricultural Reuse Schemes formulated for Kilifi Town have been worked out on the following basis;
  a) Project Implementation to be carried out within the 2040 design horizon
  b) The Cost of Civil Works constitute the following fraction of the components total costs;
      • Pumping station – 60%
      • Rising main – 100%
      • Lined Pond (Reuse water reservoir) – 100%
      • Constructed Wetland – 100%

A summary of the Capital Costs for the Agricultural Wastewater Reuse Scheme is given in **Table 10.19** below.

**Table 10.19: Capital Cost for Agricultural Wastewater Reuse Scheme - Kilifi**

| S/No. | Component | Cost, Kshs | Cost, USD |
|---|---|---|---|
| **1** | **Land Acquisition** | **8,550,000** | **83,010** |
| **2** | **Civil Works** | **374,774,094** | **3,638,583** |
| 2.1 | Pumping Station | 22,211,574 | 215,646 |
| 2.2 | Rising Main | 141,562,521 | 1,374,393 |
| 2.3 | Overflow Sewer & Manholes | 112,500,000 | 1,092,233 |
| 2.4 | Storage Pond | 98,500,000 | 956,310 |
| **3** | **Electro-Mechanical Works** | **14,807,716** | **143,764** |
| 3.1 | Pumping Stations | 14,807,716 | 143,764 |
|  | **Total Capital Cost** | **398,774,094** | **3,865,357** |

### 10.6.6.2  Operation and Maintenance Costs

The Operation and Maintenance Costs for the Scheme have been worked out on the following basis;
  a) Electricity Costs at the Pumping Stations assumed to increase annually at 4.6% p.a.
  b) Annual Maintenance Costs of the Schemes calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works
  c) Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule.

A summary of the Annual Operations & Maintenance Costs for the Scheme in the first year of operation is given in **Table 10.20**.

**Table 10.20: Annual Operations & Maintenance Costs**

| S/No. | Component | Cost, Kshs | Cost, USD [1] |
|---|---|---|---|
| 1 | Maintenance Costs | 5,232,590 | 50,802 |
| 2 | Electricity Costs | 7,343,674 | 71,298 |
| 3 | Staff Costs | 960,000 | 9,320 |
|  | **Total O & M Cost** | **13,536,264** | **131,420** |

[1] **– 1 USD = 103 Kshs**

### 10.6.6.3 Net Present Value

Net Present Value (NPV) is one of the commonly used criteria for comparing economic viability of projects/Schemes. When the unit NPV of a scheme is derived for the unit of performance indicator, incremental cost (marginal cost) is obtained.

The Net Present Values of the Scheme has been worked out on the following basis;
- a) Discount Rate/Cost of Capital - 5%
- b) Economic Life of Scheme - 20 years
- c) 10 Years Assent Renewal Period for the Electro-Mechanical components
- d) Substantial completion of the scheme expected at the end of the 2nd year of implementation of the Medium-Term Plan Works (2023) and thus, scheme operation to commence in the 3rd year (2024)

The Net Present Value for the Agricultural Wastewater Reuse Scheme for Kilifi Town is **Kshs. 525,707,089**.

### 10.6.6.4 Additional Cost for Wastewater Reuse Scheme

Treated wastewater for reuse in Kilifi Town will be conveyed to the agricultural reuse without any advanced tertiary treatment.

However, additional costs are to be incurred besides the costs of wastewater conveyance and treatment.

This additional cost has been determined as follows;

- NPV of the Scheme for 20-year period     = Ksh. 525,707,089
- Gross volume of reuse water pumped from the WWTP per day     = 12,000 m³/d
- Gross volume of reuse wastewater conveyed during 20-year period     = 87,600,000 m³
- Unit additional cost incurred during 20 year period     $= \dfrac{469,618,450}{89,060,000}$

    = <u>Ksh 6.00 per m³</u>

**Based on the information above, the additional Cost of Storing and Conveying wastewater for Agricultural reuse is; <u>Ksh 6.00 per m³.</u>**

### 10.6.6.5 Conclusion

The following conclusions are derived from the assessment of Wastewater Reuse in Kilifi;
- a) Agriculture is the most suitable wastewater reuse applications in Kilifi Town
- b) Additional cost for conveyance and storage of Agricultural Wastewater Reuse is lower than that of treating and conveying potable water based on the comparison;
   - i. Additional unit cost for conveyance and storage of Agricultural Wastewater Reuse in Kilifi Town is approximately **Ksh. 6.00 per m³**
   - ii. Unit cost of abstracting, treating and conveying potable water is Ksh. **13.62 per m³** (Feasibility Study for Kapsoya Treatment Works - 2015).
- c) Detailed studies/research should be carried out to address the following salient issues;
   - i. Tariffs for wastewater reuse;
      - Affordability of Agricultural Wastewater Reuse by farmers
      - Cost of irrigation systems and conveyance to the farms
   - ii. Establishment of reuse policy and qualitative guidelines
   - iii. Awareness and cultural acceptance on wastewater reuse through public outreach and education programs
   - iv. Development of Agricultural Wastewater Reuse Management Plan which will include system assessment, quality control and monitoring
- d) Institutional arrangement is vital among CWSB, KIMAWASCO, organized community groups and private sector for the success of the Agricultural Wastewater Reuse System.

## 11.0  FINANCIAL AND ECONOMIC ANALYSIS FOR SELECTED DEVELOPMENT STRATEGY

### 11.1  Background

This chapter provides results for financial, economic and social analysis for the investments associated with the Kilifi Wastewater Management Scheme. The data used in the financial analysis has been sourced from the various studies undertaken in the development of this Master Plan and other relevant Reports.

### 11.1.1  Water and Sanitation Sector Organization Structure

### 11.1.1.1  Existing Sector Policies

Prior to 2002, the performance of the water and sanitation sector in Kenya faced various challenges. Some of the key challenges include;

- lack of a comprehensive policy, institutional and legal framework
- centralized decision making
- lack of adequate financing mechanism

Water Sector reforms were initiated to overcome these challenges and their implementation started in 2001. The reforms have been enforced through enactment of the Water Act 2002 which was done in March 2003.

The Water Act 2002 separated water resources management, water services provision; policy and regulation; and decentralized service provision with greater autonomy to the water sector institutions. It gave rise to the institutions such as Water Services Boards (WSBs), Water Service Providers (WSPs), Water Resources Management Authority (WRMA) and Water Services Regulatory Board (WASREB).

The institutional set up under the Water Act 2002 is shown in the **Figure 11.1** below:
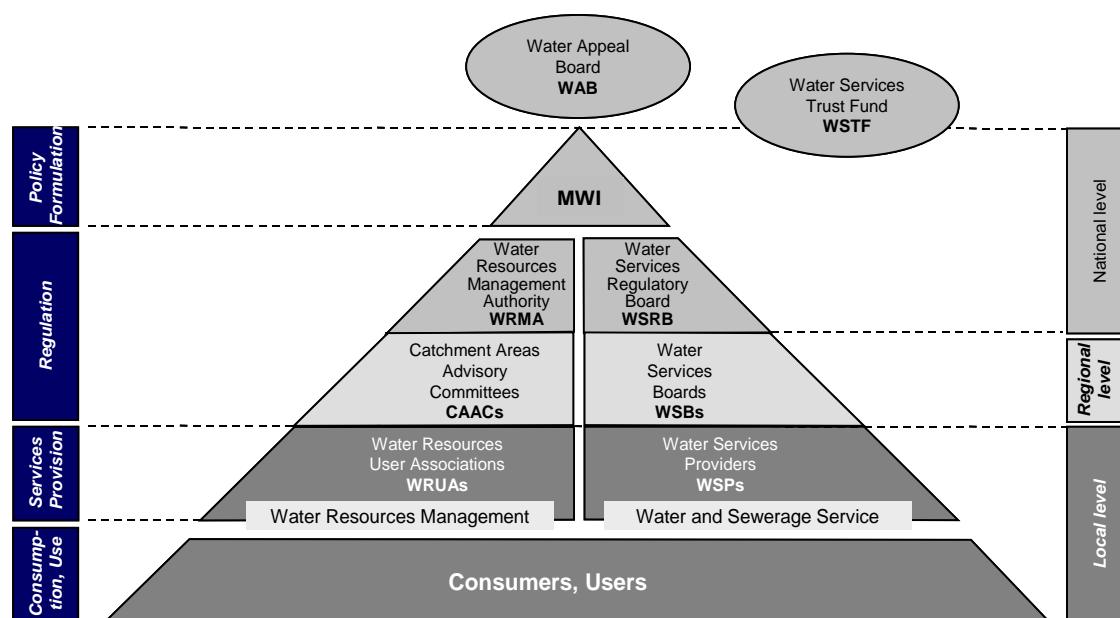


**Figure 11.1: Institutional Set-up of Water Act 2002**

In this set-up, the relationship between WSB and WASREB is governed through a license issued by WASREB while that between WSB and the WSPs is governed through a service provision agreement in which targets are set for the WSPs.

In the New Constitution dispensation (CoK 2010), water and sanitation services are part of the devolved functions of the 47 County Governments. Thus, Water Act 2002 has been reviewed into a new legislation, as Water Act 2016, to be in accordance to the new constitution. Under the New Water Act 2016, Cabinet Secretary is empowered, in consultation with County Governments to provide a national water sector investment and financing plan aggregated from the County Government plans which shall provide details such as the time frames and the investment programs for the Plans.

The Water Act 2016 also requires the Water Service Boards to be transformed into Waterworks Development Agencies by notice in the Gazette by the Cabinet Secretary.

The powers and functions of the proposed Waterworks Development Agency include:

a) Undertaking the development, maintenance and management of the national public water works within its area of jurisdiction

b) Operating the waterworks and provide water services as a water service provider, until such a time as responsibility for the operation and management of the waterworks are handed over to a county government, joint committee, authority of county governments or water services provider within whose area of jurisdiction the waterworks is located

c) providing reserve capacity for purposes of providing water services where pursuant to section 103, the Regulatory Board orders the transfer of water services functions from a defaulting water services provider to another licensee

d) Providing technical services and capacity building to such county governments and water services providers within its area as may be requested

e) Providing to the Cabinet Secretary technical support in the discharge of his or her functions under the Constitution and this Act

### 11.1.1.2  Status of Water and Sanitation Coverage

Kenya is a water stressed country with a low per capita annual freshwater endowment. Access to water and sanitation is low because of limited water resources development and ageing/dilapidated infrastructure. Access to water and sanitation falls below the Sustainable Development Goal (SDG) targets of universal access. However, some parts of the Country have improved access than others.

Despite increased investments and improvements in levels of access in the last 5 years, the rapid population increase, urbanization and economic growth strain the existing water resources and infrastructure and hinder efforts towards achieving the sector SDGs. Furthermore, catchment degradation has increased the country's vulnerability to climate change with the high inter-annual and intra-annual rainfall variability resulting in frequent and severe droughts and floods. Water security is hence crucial to attainment of Vision 2030 aspirations and sustained economic development.

### 11.1.1.3  Sector Strategies

After enactment of Water Act 2002, the Ministry of Water and Irrigation (MWI) developed strategic objectives. These include:

i.   Accelerating the implementation of water sector reforms

ii.   Improving the sustainable management of water resources

iii.   Improving the provision of water and sewerage services

iv.   Improving utilization of land through irrigation and land reclamation

v.   Strengthening institutions in the ministry and the water sector

vi.   Mobilizing resources and promoting efficiency in their utilization

vii.   Improving the management and access to water resources information

MWI also developed the Water Sector Strategic Plan (WSSP; 2010 – 2015) to ensure that water resources are protected, harnessed and sustainably managed for all competing uses and Strategic Plan (2013-2017) to increase access to clean, safe water and sanitation services.

In addition, the National Water Resources Management Strategy (NWRMS 2010-2016) aims to increase the per capita water storage levels in Kenya from $5.3m^3$ to $25m^3$ by 2030.

### 11.1.1.4  Regulation

Among the sector institutions, WASREB is mandated to set rules and enforce standards that guide the sector towards ensuring that consumers are protected and have access to adequate, efficient, affordable and sustainable services. They undertake tariff reviews to ensure cost-recovery for institutions to meet future demands. In efforts of promoting the commercialization of water service delivery, they have permitted private operators to run the urban water utilities.

WRMA issues water permits to the WSBs and monitors their compliance.

### 11.1.1.5  Coast Water Services Board

The Coast Water Services Board (CWSB) was established through a Gazette Notice No. 1328 of 27th February 2004 to undertake the mandate of WSB in the jurisdiction of the coastal area. CWSB has contracted the Mombasa Water Company (MOWASSCO), Kilifi-Mariakani Water Company (KIMAWASCO), Kwale Water Company (KWAWASCO), Malindi Water Company (MAWASCO), Lamu Water Company (LAWASCO), Taita-Taveta Voi Water Company (TAVEVO) and Tana Water and Sanitation Company (TAWASCO) with the dedicated mandate of water services provision in their respective areas.

The main responsibilities undertaken by CWSB include asset development and supervision of the WSPs. In addition to these, CWSB is currently operating the Bulk Water System while awaiting setting-up and operationalization of Bulk Water Company.

### 11.1.1.6  Kilifi – Mariakani Water and Sewerage Company Limited (KIMAWASCO)

Kilifi-Mariakani Water and Sewerage Company Ltd (KIMAWASCO)  was incorporated on 5th November 2005, as a private company limited by shares to give it autonomy and enable it operate commercially. The company however started operations on 1 July 2006. The major shareholders of the company is Kilifi County. The operations of the company effectively started in July 2006 when the Board of Directors was appointed. The mandate of the company is to provide cost effective and affordable quality water and sanitation services to the residents of in Kilifi and Kaloleni Districts under a service provision agreement.

The mandate of the company is to provide cost effective and affordable quality water and sanitation services in the area of jurisdiction. The Company's mandate includes;
   a)  Provide quality and economical water and sanitation services to consumers
   b)  Billing for water and sanitation services and ensure timely collection of revenues
   c)  Routinely maintain water and sanitation services infrastructure (depending on size of pipe)
   d)  Ensure compliance with standards and licensing requirements set by CWSB (as stipulated by Service Provision Agreement - SPA)

### 11.1.2  Tariffs

### 11.1.2.1  Introduction

Water Tariffs are identical for all the Water Service Providers under contract with CWSB. In cases where the tariff has been increased, approval by WASREB is mandatory. WASREB can also mandate WSB to formulate tariff adjustment.

In February 2010 water tariff adjustment was implemented. Where there is a sewer connection, a surcharge of 75% of the relevant water tariff applies. Other charges associated with tariff include meter rental, septic tank evacuation services etc.

### 11.1.2.2  Tariff Adjustments

It is the responsibility of the Water Service Boards (WSBs) and Water Service Providers (WSPs) to set/ adjust tariffs in accordance with the costs of operation and maintenance. This is formulated in consideration of the commercial orientations, transparent accounting, long term investment programs, and social and equity aspects.

Tariff adjustments are crucial for full cost recovery of Projects and facilitation of long term infrastructure requirements as envisaged in the vision 2030 e.g. target water and sewer connections.

The tariff adjustment proposed for the WSP should also meet the objectives of economic efficiency, equity, fairness, resource conservation, ease of implementation and political acceptability.

There are three types of tariff adjustments, as described in the Tariff Guidelines:

(i)  Regular Tariff Adjustments based on the WSP's business plan
(ii)  Extraordinary Tariff Adjustments when the cost structure undergoes significant changes
(iii)  Automatic Tariff Adjustments every 12 months which might be part of a service provision agreement with a WSP

In 2008, an Extraordinary Tariff Adjustment was granted to all WSPs as an interim measure to assist them meet their operation and maintenance costs. Sewer Tariffs are part of the tariff adjustments and is aimed at ensuring full cost recovery for sewerage projects. However, full cost recovery tariffs result to higher sewer tariffs which make the service provision unaffordable for many households.

CWSB proposes a tariff adjustment in the project life to cater for the increase in operations costs and to allow servicing of the loans used for implementing the infrastructure developments. A more conservative approach would be to increase the sewerage tariff to the level of the water tariff.

Details of current and proposed tariffs are given in **Table 11.1** below and **Table 11.2** on **Page 11-5**

**Table 11.1: Current and Proposed water and sewerage Tariffs - KIMAWASCO**

| Current Tariff | | Proposed Tariffs | | | | |
|---|---|---|---|---|---|---|
| | | [2023 – 2025] | | | [2026 – 2040] | |
| Consumption Block (m³) | Water Tariff Kshs/m³ | Consumption Block (m³) | Water Tariff Kshs/m³ | Sewer Tariff Kshs/m³ | Water Tariff Kshs/m³ | Sewer Tariff Kshs/m³ |
| **Domestic/Residential** | | | | | | |
| 0-6 | 50.00 | 0-6 | 75.00 | 56.25 | 86.67 | 65.00 |
| 7-20 | 75.00 | 7-20 | 85.00 | 63.75 | 130.00 | 97.50 |
| 21-50 | 97.50 | 21-50 | 105.00 | 78.75 | 169.00 | 126.75 |
| 51-100 | 120.00 | 51-100 | 140.00 | 105.00 | 208.00 | 156.00 |
| 101-300 | 150.00 | 101-300 | 180.00 | 135.00 | 260.00 | 195.00 |
| >300 | 227.50 | >300 | 200.00 | 150.00 | 225.00 | 168.75 |
| **Commercial/Industrial/Government Institutions** | | | | | | |
| 0-6 | 50.00 | 0-50 | 95.00 | 71.25 | 109.25 | 81.95 |
| 7-20 | 75.00 | | | | | |
| 21-50 | 97.50 | | | | | |
| 51-100 | 120.00 | 51-100 | 140.00 | 105.00 | 161.00 | 120.75 |
| 101-300 | 150.00 | 101-200 | 175.00 | 131.25 | 201.25 | 150.95 |
| >300 | 227.50 | >200 | 225.00 | 168.75 | 258.75 | 194.00 |
| **Public Boarding Schools/Universities and Colleges** | | | | | | |
| 0-600 | 56.00 | 0-600 | 65.00 | 48.75 | 74.75 | 56.00 |
| 600-1200 | 75.00 | 600-1200 | 75.00 | 56.25 | 86.25 | 64.70 |
| >1200 | 200.00 | >1200 | 200.00 | 150.00 | 230.00 | 172.50 |
| Community Water Supply | 150.00 | | 150.00 | 112.50 | 172.50 | 129.00 |
| Water Kiosks | *35.00* | | 35.00 | 26.25 | 40.25 | 30.00 |

**Table 11.2: Other charges**

| Service | Charge in Kshs |
|---|---|
| Connection fee ½ to 1 inch | 2,500 |
| Connection fee 1½ inch to 3 inches | 7,500 |
| Connection fee above 3 inches | 15,000 |
| Reconnection fee – normal | 500.00 & double deposit for every default to a max of 2.5 time the bill |
| Reconnection fee – at mains | 5000 and double deposit or the cost of reconnection whichever is higher |
| Illegal connection-Commercial, Industry, Construction (Fraud) | 30,000 and double deposit |
| Illegal connection (Fraud) – Domestic | 15,000 and double deposit |
| Tanker – 8,000 litres | 2,500 per tanker supplied within the Kilifi area |
| Replacement of stolen or damaged meters | 100% of the market cost of the meter |
| Exhauster services | 5,000 for other customers and 4,000 for informal settlements |

### 11.1.3  Kilifi Wastewater Management Scheme Development Costs

#### 11.1.3.1  Capital Development cost

The implementation costs of the proposed Wastewater Management Scheme include construction of Sewerage System (sewers and pumping stations) and Wastewater Treatment Plant (Capacity at ultimate horizon of year 2040 - 12,000 m³/d). A summary of the capital development cost of the Project is given in **Table 11.3** below.

**Table 11.3: Summary of Project Capital Development Costs**

| Component | Medium term (2021 - 2025), Kshs | Long-term (2026 - 2040), Kshs | Total, Kshs |
|---|---|---|---|
| Land | 150,000,000 | - | 150,000,000 |
| Sewerage System | 917,256,658 | 1,074,002,234 | 1,991,258,892 |
| Waste Water Treatment Plant | 736,979,575 | 499,232,584 | 1,236,212,160 |
| **Total** | **1,804,236,233** | **1,573,234,819** | **3,377,471,052** |

The above costs include Physical and Price Escalation Contingencies, Taxes and Duties and Preliminary and General Items and Consultant Fees. The total investment for the project is **Kshs. 3,377,471,052**.

#### 11.1.3.2  Operation and Maintenance Costs

The Operations and Maintenance costs comprise of Salaries / Wages, Replacement Costs, and Electricity Charges. The Operation and Maintenance Costs have been determined annually and includes annual increase due to increased sewer connections.

#### 11.1.3.3  Annual Project Expenditures

Considering the Capital and Operations / Maintenance Costs of the Project, a schedule of Annual Project Expenditures has been formulated and is given in **Table 11.4** on **Page 11-6**.

**Table 11.4: Schedule of Annual Project Expenditures**

| Year | Project Cost, Kshs | O&M, Kshs | Depreciation, Kshs | Total Cost, Kshs |
|------|------|------|------|------|
| 2021 | 451,059,058 | | | 451,059,058 |
| 2022 | 451,059,058 | | | 451,059,058 |
| 2023 | 451,059,058 | 45,586,386.29 | 52,475,626.37 | 549,121,071 |
| 2024 | 451,059,058 | 45,737,338.03 | 69,967,501.83 | 566,763,898 |
| 2025 | - | 45,909,624.29 | 69,967,501.83 | 115,877,126 |
| 2026 | 157,323,482 | 46,081,986.69 | 74,866,918.86 | 278,272,387 |
| 2027 | 157,323,482 | 46,261,933.03 | 80,967,855.54 | 284,553,270 |
| 2028 | 157,323,482 | 46,449,797.02 | 87,068,792.21 | 290,842,071 |
| 2029 | - | 46,645,927.01 | 87,068,792.21 | 133,714,719 |
| 2030 | 235,985,223 | 46,850,686.73 | 96,220,197.23 | 379,056,107 |
| 2031 | 314,646,964 | 47,064,455.87 | 100,134,871.91 | 461,846,292 |
| 2032 | 393,308,705 | 47,287,630.86 | 107,100,014.93 | 547,696,351 |
| 2033 | 157,323,482 | 47,520,625.55 | 104,913,752.94 | 309,757,860 |
| 2034 | - | 47,763,872.00 | 96,626,554.28 | 144,390,426 |
| 2035 | - | 48,017,821.29 | 96,626,554.28 | 144,644,376 |
| 2040 | | 48,282,944.36 | 94,937,607.75 | 143,220,552 |
| 2045 | | 48,559,732.84 | 92,047,141.58 | 140,606,874 |
| 2046 | | 48,848,700.01 | 89,156,675.41 | 138,005,375 |

## 11.2   Financial Analysis

### 11.2.1   Key Assumptions

The following assumptions have been made in the financial analysis:

- The project has an economic life of 30 years
- Two Phases of Implementation: Medium Term (2021 - 2025) and Long-Term (2026 - 2040)
- Project costs incurred based on a disbursement schedule (Refer to **Volume 2 of this Report**)
- Cost of capital (discount rate) assumed to be 5%
- Main source of revenue is sewer billings
- Sewer connections will increase with the water connections
- 80% of water consumed is converted into wastewater
- Annual increase in Operations and Maintenance Costs throughout the project life
- Assumed Revenue Collection efficiency of 90% throughout the period of analysis
- Annual population growth rate of 4.0 to 4.6% up to year 2040
- Average of 6 members per household
- About 60% of health expenditure in Kilifi is due to waterborne diseases
- Health expenditure per capita per year assumed to be USD 13 (Kshs. 975).
- By year 2040, the Wastewater Treatment Plant will have treated a cumulative volume of 56,345,000 m$^3$
- Tourists and Visitors to Kilifi will increase by 0.1% and result to increase in revenue due to tourism by 0.1% of the current amount generated by tourist per annum.
- Investment comprises 82% civil works and 18% electromechanical.
- Depreciation is on straight line basis, with civil works having a useful life of 40 years and electromechanical 10 years' useful life.

### 11.2.2   Methodology for Financial Analysis

The financial analysis has been undertaken using project based financial model developed for modelling the financial performance of a Sewerage Project. The Microsoft excel based model incorporates all the important variables of financial performance and spans for a period of 26 year.

Its main components include: Investment Cost, Revenue Generated, Operating and Maintenance Cost and other Economic Factors such as Projected Water Demand and Population.

The outputs for the model include the, Project Financial Statements and Financial Ratios / Performance Indicators.

In determining the financial viability of the Kilifi Wastewater Management Scheme the following activities were undertaken:

(i) identifying and quantifying the Project Costs and Maintenance

(ii) calculating the project revenues

(iii) Estimating the average incremental financial cost, financial net present value and financial internal rate of return (FIRR)

FIRR is the rate of return at which the present value of the stream of incremental net flows in financial prices is zero. If the FIRR is equal to or greater than the financial opportunity cost of capital, the project is considered financially viable. Thus, financial benefit-cost analysis covers the profitability aspect of the project.

### 11.2.3 Project Revenues

The projects gross revenues are calculated as the total revenues from sewerage services less billings not recovered while net incomes are calculated as the difference between gross revenues and costs (capital development and O&M costs). A collection efficiency of 90% has been adopted in the analysis.

A summary of the Project Revenues is shown in **Table 11.5** below.

**Table 11.5: Summary of Project Revenues**

| Year | Revenue Generated, Kshs | Collection Efficiency | Average Revenue, Kshs |
|------|------------------------|----------------------|----------------------|
| 2023 | 108,101,600.06 | 90% | 97,291,440 |
| 2024 | 108,101,600.06 | 90% | 97,291,440 |
| 2025 | 135,360,062.07 | 90% | 121,824,056 |
| 2026 | 135,360,062.07 | 90% | 121,824,056 |
| 2027 | 196,004,977.41 | 90% | 176,404,480 |
| 2028 | 196,004,977.41 | 90% | 176,404,480 |
| 2029 | 196,004,977.41 | 90% | 176,404,480 |
| 2030 | 417,021,310.80 | 90% | 375,319,180 |
| 2031 | 417,021,310.80 | 90% | 375,319,180 |
| 2032 | 417,021,310.80 | 90% | 375,319,180 |
| 2033 | 417,021,310.80 | 90% | 375,319,180 |
| 2034 | 417,021,310.80 | 90% | 375,319,180 |
| 2035 | 417,021,310.80 | 90% | 375,319,180 |
| 2036 | 417,021,310.80 | 90% | 375,319,180 |
| 2037 | 417,021,310.80 | 90% | 375,319,180 |
| 2038 | 417,021,310.80 | 90% | 375,319,180 |
| 2039 | 417,021,310.80 | 90% | 375,319,180 |
| 2040 | 654,701,371.84 | 90% | 589,231,235 |
| 2041 | 654,701,371.84 | 90% | 589,231,235 |
| 2042 | 654,701,371.84 | 90% | 589,231,235 |
| 2043 | 654,701,371.84 | 90% | 589,231,235 |
| 2044 | 654,701,371.84 | 90% | 589,231,235 |
| 2045 | 654,701,371.84 | 90% | 589,231,235 |
| 2046 | 654,701,371.84 | 90% | 589,231,235 |

### 11.2.4　Project Financial Statement

The projected Income and expenditure statement for the project is summarized in **Table 11.6** below.

**Table 11.6**: **Projected Financial Statement of the Project**

| | Project Income and Expenditure Financial statement (Kshs) | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Total Project Revenue | Billings Not Recovered | Net Project Revenue | Operations & Maintenance | Annual Depreciation | Total Expenditure | Net Revenue |
| 2023 | 108,101,600 | 10,810,160 | 97,291,440 | 45,586,386 | 52,475,626 | 98,062,025 | -770,585 |
| 2024 | 108,101,600 | 10,810,160 | 97,291,440 | 45,737,338 | 69,967,502 | 115,704,853 | -18,413,413 |
| 2025 | 135,360,062 | 13,536,006 | 121,824,056 | 45,909,624 | 69,967,502 | 115,877,140 | 5,946,916 |
| 2026 | 196,004,977 | 19,600,498 | 176,404,480 | 46,081,987 | 74,866,919 | 120,948,919 | 55,455,560 |
| 2027 | 196,004,977 | 19,600,498 | 176,404,480 | 46,261,933 | 80,967,856 | 127,229,803 | 49,174,677 |
| 2028 | 196,004,977 | 19,600,498 | 176,404,480 | 46,449,797 | 87,068,792 | 133,518,604 | 42,885,876 |
| 2029 | 196,004,977 | 19,600,498 | 176,404,480 | 46,645,927 | 87,068,792 | 133,714,734 | 42,689,746 |
| 2030 | 417,021,311 | 41,702,131 | 375,319,180 | 46,850,687 | 96,220,197 | 143,070,899 | 232,248,281 |
| 2031 | 417,021,311 | 41,702,131 | 375,319,180 | 47,064,456 | 100,134,872 | 147,199,343 | 228,119,836 |
| 2032 | 417,021,311 | 41,702,131 | 375,319,180 | 47,287,631 | 107,100,015 | 154,387,662 | 220,931,518 |
| 2033 | 417,021,311 | 41,702,131 | 375,319,180 | 47,520,626 | 104,913,753 | 152,434,395 | 222,884,785 |
| 2034 | 417,021,311 | 41,702,131 | 375,319,180 | 47,763,872 | 96,626,554 | 144,390,443 | 230,928,737 |
| 2035 | 417,021,311 | 41,702,131 | 375,319,180 | 48,017,821 | 96,626,554 | 144,644,393 | 230,674,787 |
| 2036 | 417,021,311 | 41,702,131 | 375,319,180 | 48,282,944 | 94,937,608 | 143,220,570 | 232,098,610 |
| 2037 | 417,021,311 | 41,702,131 | 375,319,180 | 48,559,733 | 92,047,142 | 140,606,893 | 234,712,287 |
| 2038 | 417,021,311 | 41,702,131 | 375,319,180 | 48,848,700 | 89,156,675 | 138,005,394 | 237,313,786 |
| 2039 | 417,021,311 | 41,702,131 | 375,319,180 | 49,150,382 | 89,156,675 | 138,307,076 | 237,012,104 |
| 2040 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 84,820,976 | 134,286,333 | 454,944,902 |
| 2041 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 79,040,044 | 128,505,401 | 460,725,833 |
| 2042 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 71,813,878 | 121,279,236 | 467,951,998 |
| 2043 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,771 | 470,842,464 |
| 2044 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,771 | 470,842,463 |
| 2045 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,772 | 470,842,463 |
| 2046 | 654,701,372 | 65,470,137 | 589,231,235 | 49,465,337 | 68,923,412 | 118,388,772 | 470,842,462 |

The Key outputs of the Financial Analysis Model include the Benefit Cost (BC) ratio and Discounted Measures such as Net Present Value (NPV) and Financial Internal Rate of Return (FIRR). A summary of these key outputs are described in the subsequent sub-sections while the detailed results for the analysis are presented in **Volume 2 of this Report**.

### 11.2.5　Cost Benefit Analysis

The Benefit Cost (BC) ratio of the project was computed using the following formula:

*BC Ratio = present value of the project revenues/ project investment cost*

From the analysis, the BC ratio for the project is **1.51** with an assumed discounting rate/cost of capital of 5%. However, at discounting rate/cost of capital of 8% and 10%, the resulting BCs are **1.22 and 1.08.** These BC ratios are greater than 1 and indicate that the project is financially viable at a discounting rate/cost of capital less than 10%.

### 11.2.6  The Net Present Value (NPV)

From the Financial Analysis, the NPV values for the project are **Ksh 1,326,806,064** at 5% cost of capital and **Kshs 435,216,677** at 8% cost of capital. The positive NPVs suggest that the project is financially viable.

### 11.2.7  Financial Internal Rate of Return

The Financial Internal Rate of Return (FIRR) for the project is **11.30%** This FIRR is greater than the assumed cost of capital of 5% and confirm project viability.

### 11.2.8  Sensitivity Analysis

The project's financial ratios have been subjected to sensitivity analysis as follows:

**Scenario 1: 20% shocks**
- 20% increase in investment cost
- 20% decrease in revenues
- 20% increase in operation and maintenance costs

**Scenario 2: 10% shocks**
- 10% increase in investment cost
- 10% decrease in revenues
- 10% increase in operation and maintenance costs

A summary of the Sensitivity Analysis is given in **Table 11.7** below

**Table 11.7: Summary of Sensitivity Analysis**

| Type of Variation | NPV (KSHS) | FIRR (%) |
|---|---|---|
| **20 % shocks** | | |
| Increasing the project cost by 20% | -151,190,052 | 9% |
| Reducing the total net income by 20% | -224,490,306 | 8% |
| Increasing O&M cost by 20% | 23,270,072 | 10% |
| **10 % shocks** | | |
| Increasing the project cost by 10% | -11,521,890 | 10% |
| Reducing net income by 10% | -48,172,017 | 10% |
| Increasing O&M cost by 10% | 103,940,082 | 11% |

The results on **Table 11.7** above show that the project's viability is affected when subjected to shocks of increasing project cost by 10 or 20% and also reducing net income by 10 or 20%.

### 11.2.9  Conclusion of Financial Analysis

The results of the cost-benefit analysis confirm that the project has favourable BC ratios of between **1.08** to **1.51**. The financial analysis confirms that the project has positive NPVs of **Ksh 1,326,806,064** at 5% cost of capital and **Ksh 453,216,677** at 8% cost of capital and Financial Internal Rates of Return (FIRR) of **16**%. Sensitivity analyses also indicate that the project viability can withstand shocks of 20% increase in O& M costs but is susceptible to shocks of 20% on project cost and net income. This confirms that the project is financially viable.

## 11.3 Economic Analysis

### 11.3.1 General

The following sub-section presents the economic analysis of the selected Wastewater Management Scheme for Kilifi Town. It is envisaged that the goal of the Project comprises of improved health and living conditions, reduction of poverty, increased productivity and economic growth of the Project Area.

The purpose of the economic analysis of projects is to inform a better allocation of scarce resources. Detailed results of the analysis of the analysis are given in Volume 2 of this Report.

### 11.3.2 Methodology

The assessment is based on the analysis of the economic impacts and returns in the conventional cost benefit approach i.e. the Capital and Operational and Maintenance Costs in economic terms over the project life are compared to the Economic Benefits of increased Sanitation Services.

To assess the economic viability of the project, the following steps have been undertaken:
   i. Costs and benefits were identified and quantified (in physical terms)
   ii. Costs and benefits were valued to the extent feasible, in monetary terms
   iii. Economic Internal Rate of Return (EIRR) or Economic Net Present Value (NPV) discounted at Economic Opportunity Cost of Capital (EOCC) of 5%, 10% and 12% by comparing benefits with the costs

The EIRR is the rate of return for which the present value of the net benefit stream becomes zero, or at which the present value of the benefit stream is equal to the present value of the cost stream. For a project to be acceptable, the EIRR should be greater than the EOCC.

The weighted average cost of capital for the CWSB area is approximately 3%. The analysis has adopted 5% as the minimum rate of return since the projects are assumed to have considerable non-quantifiable benefits.

### 11.3.3 Key Assumptions

The assumptions considered under Financial Analysis applies for the Economic Analysis (Refer to **Sub-section 11.2.1**).

### 11.3.4 Capital Development Cost

The capital development costs adopted in the economic analysis are summarized in **Table 11.8** below:

**Table 11.8: Schedule of Capital Development Costs**

| Implementation Year | Distribution of Investments | Percentage of Disbursement | Sewerage System, Ksh | Wastewater Treatment Plant, Ksh | Land Acquisition, Ksh |
|---|---|---|---|---|---|
| 2021 | Medium Term Investment | 25% | 229,314,164 | 184,244,893 | 150,000,000 |
| 2022 | | 25% | 229,314,164 | 184,244,893 | - |
| 2023 | | 25% | 229,314,164 | 184,244,893 | - |
| 2024 | | 25% | 229,314,164 | 184,244,893 | - |
| 2026 | Long Term Investment | 10% | 107,400,223 | 49,923,258 | - |
| 2027 | | 10% | 107,400,223 | 49,923,258 | - |
| 2028 | | 10% | 107,400,223 | 49,923,258 | - |
| 2030 | | 15% | 161,100,335 | 74,884,887 | - |
| 2031 | | 20% | 214,800,446 | 99,846,516 | - |
| 2032 | | 25% | 268,500,558 | 124,808,146 | - |
| 2033 | | 10% | 107,400,223 | 49,923,258 | - |
| **Total** | | | **1,991,258,892** | **1,236,212,159** | **150,000,000** |

### 11.3.5  Project Expenditures

The annual cash flows for the capital and O&M cost is summarized in **Table 11.9** below.

**Table 11.9: Schedule of Project Expenditures**

| Year | Costs (Kshs) | | |
| --- | --- | --- | --- |
| | **Capital Cost** | **O & M costs** | **Total cost** |
| 2021 | 451,059,058 | - | 451,059,058 |
| 2022 | 451,059,058 | - | 451,059,058 |
| 2023 | 451,059,058 | 45,586,386 | 496,645,445 |
| 2024 | 451,059,058 | 45,737,338 | 496,796,396 |
| 2025 | - | 45,909,624 | 45,909,624 |
| 2026 | 157,323,482 | 46,081,986 | 203,405,469 |
| 2027 | 157,323,482 | 46,261,933 | 203,585,415 |
| 2028 | 157,323,482 | 46,449,797 | 203,773,279 |
| 2029 | - | 46,645,927 | 46,645,927 |
| 2030 | 235,985,223 | 46,850,686 | 282,835,910 |
| 2031 | 314,646,964 | 47,064,455 | 361,711,420 |
| 2032 | 393,308,705 | 47,287,630 | 440,596,336 |
| 2033 | 157,323,482 | 47,520,625 | 204,844,107 |
| 2034 | - | 47,763,872 | 47,763,872 |
| 2035 | - | 48,017,821 | 48,017,821 |
| 2036 | - | 48,282,944 | 48,282,944 |
| 2037 | - | 48,559,732 | 48,559,733 |
| 2038 | - | 48,848,700 | 48,848,700 |
| 2039 | - | 49,150,381 | 49,150,382 |
| 2040 | - | 49,465,337 | 49,465,337 |
| 2041 | - | 49,465,337 | 49,465,337 |
| 2042 | - | 49,465,337 | 49,465,337 |
| 2043 | - | 49,465,337 | 49,465,337 |
| 2044 | - | 49,465,337 | 49,465,337 |
| 2045 | - | 49,465,337 | 49,465,337 |
| 2046 | - | 49,465,337 | 49,465,337 |

### 11.3.6  Conversion to Economic Prices

The capital cost has been converted to their economic prices in real 2016 price terms. This excludes: Sunk Costs, Working Capital, Transfer Payments such as Taxes, duties and subsidies, External Costs and Depreciation.

### 11.3.7  Water and Wastewater Projections

**Table 11.10: Projected Water and Wastewater conditions**

| Scenario | 2015 | 2020 | 2025 | 2030 | 2040 |
|---|---|---|---|---|---|
| | m³/d | | | | |
| Projected Water Demand | 6,390 | 7,850 | 9,736 | 12,297 | 19,114 |
| Projected Water Supply | 3,195 | 3,925 | 4,868 | 9,837 | 13,380 |
| Wastewater Generation with Regular Water Supply & 100% Sewer Connections | 6,280 | 7,510 | 9,088 | 11,140 | 17,071 |
| Wastewater Generation with projected build-out of Sewer Connections and Suppressed Water Supply | 2,505 | 2,871 | 3,595 | 7,648 | 12,007 |

In the Economic Analysis, the projected wastewater generation with the projected build-out of Sewer Connections and Suppressed Water Supply has been adopted.

### 11.3.8 Future Without Project Situation

Kilifi Town currently lacks a functional water-borne sewerage system. If the proposed wastewater management strategy is not implemented, the service area will continue to rely on the on-plot sanitation systems such as septic tanks and latrines. These systems are unsustainable and pose hazard to both the public health and the environment resulting to pollution of water bodies (ocean and rivers) and increased occurrence of water-borne diseases.

### 11.3.9 Valuation of benefits

### 11.3.10 Improvement of Water Bodies (non-use value)

Tourism is the main economic activity in Kilifi Town. At present, raw sewage is released into the environment including water bodies such as the ocean beaches. The implementation of the proposed wastewater management sscheme will ensure proper treatment and disposal of wastewater and result to clean and more attractive beaches with the effect of boosting the economy of Kilifi through increased number of visiting tourists and investors.

It has been assumed that the tourists and visitors to Kilifi will increase by 0.1% and increase the revenue for the beaches by 0.1% of the tourist spend per annum.

The resulting benefits have been calculated based on the following variables & their assumed values;

- Number of Tourists and Visitors Per Month (N) - 50,000
- Average expenditure per day in in USD - 200
- Exchange rate USD to Kshs (E) - 101
- Number of Month in a year (M) - 12
- Percentage contribution - 0.1 %

Total expenditure by tourists & visitors = (50,000*200*101*12) *0.1% = **Ksh. 12,120,000** per annum.

### 11.3.10.1 Health Benefits

Improved sanitation systems are expected to generate significant health benefits to be measured by the reduction in waterborne diseases and thereby reduced household expenditure in health, reduced work day losses from sickness or by having to care for the sick family members.

In the economic analysis, it has been assumed that about 60% of health expenditure in Kilifi results from waterborne diseases and health expenditure per capita per year is USD 13 (Kshs. 975).

### 11.3.11 Results of Economic Analysis

The Key outputs of the model are the Cost Benefit Cash Flow, Net Present Value and Economic Internal Rate of Return (EIRR). Details of these outputs are given in following sub-sections.

### 11.3.11.1 Cost Benefit Cash Flow Summary

Results of Cost and Benefit Cash Flows are presented in **Table 11.11** on **Page 11-13.**

### Table 11.11: Summary of Cost Benefit Cashflow

| Year | Investment Costs (Kshs) | | | Monetary Value of Benefits (Kshs) | | | | | | Population Served |
|------|---|---|---|---|---|---|---|---|---|---|
| | Sewerage Capital Cost | O & M costs | Total cost | Incremental Revenue | Improvement of Water Bodies (non-use value) | Cost Savings in terms of Health Benefits | Total Benefit | Net economic Benefits 12% | Net economic Benefits 10% | |
| 2021 | 451,059,058 | - | 451,059,058 | 106,804,381 | 12,120,000 | 39,193,933 | 158,118,313 | -292,940,745 | -292,940,745 | 66,998 |
| 2022 | 451,059,058 | - | 451,059,058 | 106,804,381 | 12,120,000 | 40,918,466 | 159,842,846 | -291,216,212 | -291,216,212 | 69,946 |
| 2023 | 451,059,058 | 45,586,386 | 496,645,445 | 106,804,381 | 12,120,000 | 42,718,878 | 161,643,259 | -335,002,186 | -335,002,186 | 73,024 |
| 2024 | 451,059,058 | 45,737,338 | 496,796,396 | 133,735,741 | 12,120,000 | 44,598,509 | 190,454,250 | -306,342,146 | -306,342,146 | 76,237 |
| 2025 | - | 45,909,624 | 45,909,624 | 193,652,918 | 12,120,000 | 46,560,843 | 252,333,761 | 206,424,137 | 206,424,137 | 79,591 |
| 2026 | 157,323,482 | 46,081,987 | 203,405,469 | 193,652,918 | 12,120,000 | 48,702,642 | 254,475,560 | 51,070,091 | 51,070,091 | 83,252 |
| 2027 | 157,323,482 | 46,261,933 | 203,585,415 | 193,652,918 | 12,120,000 | 50,942,963 | 256,715,881 | 53,130,466 | 53,130,466 | 87,082 |
| 2028 | 157,323,482 | 46,449,797 | 203,773,279 | 193,652,918 | 12,120,000 | 53,286,340 | 259,059,257 | 55,285,979 | 55,285,979 | 91,088 |
| 2029 | - | 46,645,927 | 46,645,927 | 412,017,055 | 12,120,000 | 55,737,511 | 479,874,566 | 433,228,639 | 433,228,639 | 95,278 |
| 2030 | 235,985,223 | 46,850,687 | 282,835,910 | 412,017,055 | 12,120,000 | 58,301,437 | 482,438,492 | 199,602,582 | 199,602,582 | 99,661 |
| 2031 | 314,646,964 | 47,064,456 | 361,711,420 | 412,017,055 | 12,120,000 | 60,983,303 | 485,120,358 | 123,408,938 | 123,408,938 | 104,245 |
| 2032 | 393,308,705 | 47,287,631 | 440,596,336 | 412,017,055 | 12,120,000 | 63,788,535 | 487,925,590 | 47,329,254 | 47,329,254 | 109,040 |
| 2033 | 157,323,482 | 47,520,626 | 204,844,107 | 412,017,055 | 12,120,000 | 66,722,808 | 490,859,863 | 286,015,755 | 286,015,755 | 114,056 |
| 2034 | - | 47,763,872 | 47,763,872 | 412,017,055 | 12,120,000 | 69,792,057 | 493,929,112 | 446,165,240 | 446,165,240 | 119,303 |
| 2035 | - | 48,017,821 | 48,017,821 | 412,017,055 | 12,120,000 | 73,002,491 | 497,139,546 | 449,121,725 | 449,121,725 | 124,791 |
| 2036 | - | 48,282,944 | 48,282,944 | 412,017,055 | 12,120,000 | 76,360,606 | 500,497,661 | 452,214,717 | 452,214,717 | 130,531 |
| 2037 | - | 48,559,733 | 48,559,733 | 412,017,055 | 12,120,000 | 79,873,194 | 504,010,249 | 455,450,516 | 455,450,516 | 136,535 |
| 2038 | - | 48,848,700 | 48,848,700 | 412,017,055 | 12,120,000 | 83,547,361 | 507,684,416 | 458,835,716 | 458,835,716 | 142,816 |
| 2039 | - | 49,150,382 | 49,150,382 | 646,844,955 | 12,120,000 | 87,390,539 | 746,355,495 | 697,205,113 | 697,205,113 | 149,386 |
| 2040 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| 2041 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| 2042 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| 2043 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| 2044 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| 2045 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| 2046 | - | 49,465,337 | 49,465,337 | 646,844,955 | 12,120,000 | 91,410,504 | 750,375,460 | 700,910,122 | 700,910,122 | 156,257 |
| | | | | | | | NPV | 267,968,361 | 554,613,517 | |
| | | | | | | | EIRR | 16% | 16% | |

**11.3.11.2 The Net Present Value (NPV)**

The NPV values for the project with resource savings (economic benefits included) at 10% and 12% cost of capital are **Kshs 554,613,517** and **Kshs 267,968,361** respectively. These suggest that the project is economically viable.

**11.3.11.3 Economic Internal Rate of Return**

Economic Internal Rate of Return (EIRR) for the project while considering the resource savings results to an economic rate of return (EIRR) of **16%** for both 12% and 10% discount rates. These confirm that the project is economically viable.

**11.3.12 Conclusion of Economic Analysis**

The results of the economic analysis after including other economic benefits showed that the project would have a **positive NPV of Kshs 554,613,517** and **EIRR of 16%** at **10%** cost of capital. These values confirm that the project is economically viable.

## 12.0   RECEIVING ENVIRONMENT AND MONITORING PROGRAM

### 12.1   Introduction

The proposed Wastewater Management Scheme for Kilifi Town involves discharging treated wastewater to a natural waterway as part of the Scheme. The Indian Ocean has been identified as the receiving environment for the proposed discharge from the proposed Wastewater Treatment Plant (WWTP) at Uhuru Farm.

The aims of this Chapter are to:

- describe the background condition of waterways in the receiving environment, including a description of key 'background' (i.e. without impacts from the proposed discharges) water quality characteristics
- describe the environmental values (EVs) and water quality objectives (WQOs) with respect to NEMA Standards of the receiving environment
- identify and describe the extent of any adverse environmental impacts to local environmental values
- monitor any changes in the receiving water

The most recent and relevant surveys of the receiving environments were undertaken as a part of the Preliminary Environmental and Social Impact Assessment (ESIA). The ESIA involved survey of the Alternative Wastewater Treatment Plant sites and the receiving waters for aquatic habitat, water quality, macrophytes, and fish.

### 12.2   Preliminary Environmental Values and Water Quality Objectives

The list of preliminary environmental values (EVs) that apply to the receiving environment is:

- aquatic ecosystem (slightly to moderately disturbed)
- stock watering
- drinking water
- primary, secondary and visual recreation
- cultural and spiritual values

Confirmation of the EVs for the receiving environment will be sought during the Detailed Environment and Social Impact Assessment Studies.

### 12.3   Monitoring Program Design

Three monitoring locations in the receiving waters / environment of Indian Ocean will be set i.e. at the discharge site, upstream and downstream of the discharge point during the Receiving Environment Monitoring Program (REMP). Flows, water quality, sediment quality, macrophytes and fish will be the key indicators for monitoring.

#### 12.3.1   Water Flows

The volume of water released from the discharge location will be measured and recorded, and flow records will be obtained from the flow measurement device installed at the Proposed WWTP.

#### 12.3.2   Bank Stability

Bank stability will be monitored twice per year at the discharge point (notionally in the wet season and post-wet season, by physical inspection to determine whether significant erosion has occurred or bank stability compromised.

The assessment will include characterization of the following parameters at the proposed wastewater discharge point:

- Bank shape
- Bank stability
- Bed stability
- Artificial bank protection measures
- Factors affecting bank stability
- Valley shape
- Channel shape
- Channel and stream width

### 12.3.3 Water Quality

Water quality at the receiving environment and background site will be monitored throughout the duration of the REMP. It is intended to sample water quality twice per year in the wet season at the proposed monitoring locations near the point of discharge on the Indian Ocean; notionally in the wet season and post-wet season. Two replicate samples will be collected per location.

The parameters to be monitored are consistent with the indicators specified in the NEMA guidelines.

At each location and during each sampling event, physical water quality measurements will be collected *in situ* using a hand-held water quality meter. The following variables will be recorded at the three locations at 30 cm depth:

- water temperature (°C)
- pH
- conductivity (µS/cm)
- dissolved oxygen (DO, mg/L)
- turbidity (NTU)

In addition, two replicate water samples will be collected from each site for analysis of the following parameters in accordance with the indicators currently monitored by NEMA:

- Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) (mg/L)
- Water hardness (mg/L)
- Major Cations (Ca, K, Mg, Na) and Anions (Cl, SO4, alkalinity) (mg/L)
- Carbonate, bicarbonate and hydroxide (m/L)
- Fluoride (mg/L)
- Nutrients (total nitrogen and total phosphorus (unfiltered) and ammonia (as N), nitrate (as N), nitrite (as N) (filtered) and filterable reactive phosphorus (FRP) (as P)) (mg/L)
- Metals and metalloids (Al, As, Ba, Be, Cd, Cr, Cu, Fe, Hg, Pb, Ni, Zn, B, Co, Mn, Mo, Se, Ag, U, V) (dissolved (filtered) and total (unfiltered) in µg/L)
- Chlorophyll-a (µg/L)
- Blue green algae (cyanobacteria) (cells/mL)
- Organochloride and organophosphate pesticides (OCPs and OPPs) (µg/L)
- Total petroleum hydrocarbons (TPH), benzene, toluene, ethylene and xylene (BTEX) and polyaromatic hydrocarbons (PAHs) (µg/L)
- Sodium absorption ratio (SAR) (mg/L)
- Colour (Hazen units)
- Silicon (mg/L)
- Faecal coliforms / e-coli (CFU/mL)
- methylene blue (MBAS) (mg/L)

Grab samples will be collected from the mid-channel at each site, 30 cm below the water's surface, by hand or by a sampling pole with clamp if required for safety reasons.

Two samples will be collected for analysis of nutrients and metals and metalloids. The first sample will be un-filtered and will be used for analysis of total nitrogen, total phosphorus and total metals. The second sample will be filtered in the field through a 0.45 µm filter, and will be used for the analysis of ammonia, nitrate, nitrite and dissolved metals.

*Sediment Quality*

Sediment quality will be monitored in conjunction with water quality monitoring.

Two replicate sediment samples from both the bed and banks will be collected and analyzed for the parameters currently monitored by NEMA and other relevant government agencies.

The following parameters will be monitored;

- particle size distribution (sieve and hydrometer)
- pH
- major cations (Ca, K, Mg, Na) and anions (Cl, SO4, alkalinity) (mg/kg)
- sodium absorption ratio (SAR)
- fluoride (mg/kg)
- nutrients (total nitrogen, total phosphorus, ammonia (as N), nitrate (as N) nitrite (as N)) (mg/kg)
- total metals and metalloids (Al, As, Ba, Be, Cd, Cr, Cu, Fe, Hg, Pb, Ni, Zn, B, Co, Mn, Mo, Se, Ag, U, V) (mg/kg)
- organochloride and organophosphate pesticides (OCPs and OPPs)
- silicon (mg/kg)
- cyanide (total) mg/kg

Where the water is shallow enough (<0.5 m deep), replicate sediment samples will be collected from the top 0.30 m of sediment on the bed and banks using a stainless-steel trowel, with the sediments transferred directly into the sampling jar provided by the analytical laboratory.

Where the water is deep or the sediment is too soft to walk in, surface sediment from the bed and banks (to 0.30 m depth) will be collected using a stainless-steel corer. The sample will be emptied into a bucket or other intermediate container, which has been thoroughly washed with ambient site water, and the sediment mixed and placed into the sample jar using a stainless-steel trowel.

*Macrophytes*

Macrophyte communities and algae abundance will be monitored twice per year: notionally in the pre-wet season and the post-wet season at the proposed monitoring locations.

At each site, macrophytes and algae will be surveyed along three 50 m by 1 m belt transects. The percent cover of floating, emergent and submerged macrophytes will be visually estimated by species, noting listed threatened and exotic (and declared noxious) species.

*Fish*

Fish communities will be monitored twice per year: notionally in the wet season and the post-wet season at the proposed monitoring sites.

Fish communities will be surveyed using a combination of backpack or boat electrofishing (depending on the nature of the waterway being sampled), seine and set nets, baited traps and dip nets. At each site, the species present and the abundance of each species by life history stage (juvenile, intermediate, adult), the length, frequency distribution for each species, and the apparent health of individuals will be recorded.

*Onsite Observations*

General physical observations will be recorded at each site during each sampling event, to provide an 'early warning' of potential adverse impacts. In particular, algal blooms, unusual deposits of sediment and floating objects (debris, oil and grease), dense growth of attached plants and insects, any evidence of chemical precipitation, any evidence of erosion and the presence of dead aquatic fauna (odour) will be recorded. If these are detected, this will trigger further investigations of recent releases, and of water and sediment quality results.

## 12.4    Data Analysis and Reporting

Interim reports will be provided after each survey event, and will provide a preliminary comparison of the results to relevant NEMA and other standards, and a preliminary discussion of potential impacts to the receiving environment.

Annual reports will also be prepared, and will include comparison to the relevant NEMA and other standards, and an assessment of potential impacts to the receiving environment.

## 13.0    PRELIMINARY ENVIRONMENT IMPACTS AND RESETTLEMENT ACTION PLAN

### 13.1    Introduction

This Chapter focuses on the potential environment and social impacts that are likely to be triggered during implementation of the proposed Wastewater System for Kilifi Town. The social safeguards in this context include Project resettlement impacts.

The implementation of the proposed Wastewater Management Scheme entails construction of the following components;

- Waste Stabilization Pond (WSPs) at an identified site at Uhuru Farm
- Trunk, Secondary and Tertiary sewers
- 11 Nr sewage pumping stations at designated locations within Kilifi Town

Once commissioned, the scheme, hereafter referred to as the Project will provide sustainable water-borne sanitation system to Kilifi Town as an improvement to the existing sanitation systems comprising of on-plot sanitation system such as pit latrines and septic tanks.

### 13.1.1    Environment Screening

This process is critical in the assessment of environment for a project as it ensures early management of environmental risks through identification of potential environmental impacts and proposals of mitigation measures. The process also helps in establishment of Project's Environmental Assessment (EA) Category (A, B, C or FI) as required by World Bank Operational Policy OP 4.01 and ranking of Project (high, medium and low risks) as required by Environmental Management and Co-ordinationAct (EMCA) 1999 amended in 2015.

The environmental components of the Project have been determined and appropriate mitigation measures proposed.  The environment components assessed include;

- Natural environment (air, water, land)
- Human health and safety
- Physical cultural resources
- Social issues which include involuntary resettlement

This Project has been classified based on the type, location, sensitivity, nature and reversibility of environmental impacts identified at screening stage as Category A and High Risk as per OP 4.01 and EMCA 1999 respectively.

This implies that the adverse environmental impacts associated with the Project are broad, diverse, beyond local site and trigger resettlement. Thus, a full Environmental and Social Assessment (ESIA) should be carried especially at the Detailed Design Stage.

### 13.1.2    Screening for Resettlement Impacts

The purpose of this stage/process is to identify social and resettlement risks and propose appropriate measures to manage the risks.

The Project has a potential of triggering Resettlement impacts. Thus, the Land Act 2012 and the World Bank Operational Policy OP 4.12 have been adopted as the main policy documents to guide on mechanism for preparation of Resettlement Action Plan.

The main principles of the Policy include:

- To prevent or minimize involuntary displacement whenever possible
- To design and implement resettlement as a sustainable development program
- To pay for lost assets at replacement cost
- To restore peoples' capacity to earn a living and their community ties
- Components necessary to realize project objectives are covered regardless of the source of financing
- Resettlement costs are considered part of project costs

The Project components are expected to result to significant resettlement of persons since the proposed site for the Wastewater Treatment Plant (Uhuru Farm / Bofa Maweni) on land parcel (LR NO Mtondia MUT/237/987/08/16 Parcel Number 254, 255 and 256) is privately owned.

The expected resettlement has the following potential effects;

- Loss of private land at the proposed sites for establishment of WWTP (WSPs)
- Loss of structures lying along the sewer alignments and its wayleave and at the proposed WWTP and Pumping Station sites during construction period
- Loss of crops and trees lying along the sewer alignments and its wayleaves and at the WWTP and Pumping Station sites during construction period

## 13.2 Guiding Legislation and Policy

Based on the scope, EMCA 1999 requires that Project activities under the proposed Wastewater Master Plan for Kilifi Town be subjected to an Environmental and Social Impact Assessment (ESIA).

The World Bank under Operation Policy OP 4.01 also requires that Environmental Assessment (EA) be carried out for Projects of such magnitude.

The, development of such Infrastructure Projects require compliance to the guiding legislations, guidelines and policies both under the Kenyan context and the World Bank. These have been dealt with under several laws, by-laws, regulations and Acts of parliament, as well as policy documents. The relevant guidelines are summarized in the following sub-sections;

### 13.2.1 Kenyan Legislations

- The Environmental Management and Coordination Act (EMCA),1999 and subsequent regulations
- Coast Development Authority Act (Cap 449)
- Forest Act 2005
- Marine Zones Act Cap 371 of 1989
- Water Act 2016
- County Government Act No. 17 of 2012
- Physical Planning Act 1996 (286)
- Occupational Health and Safety Act (OSHA 2007)
- The Public Health Act (Cap.242)

### 13.2.2 World Bank Policies and Guidelines

The Project has been assessed against the following Safeguards Policies.

- Environmental Assessment - OP 4.01
- Involuntary Resettlement - OP 4.12
- Forestry - OP 4.36, GP 4.36
- Natural Habitats - OP/BP 4.04
- Physical Cultural Resources - OP/BP 4.11
- World Bank Group Environmental Health and Safety Guidelines on Water and Sanitation

## 13.3    Scoping for Environmental and Social Impacts

The process of scoping for environmental and social impacts has been undertaken on all components of the proposed Project. The purpose of scoping is to identify significant environmental and social risks that are likely to be triggered by the Project.

The process enabled determination of the appropriate issues within the required scope and extent of the project. The aspect considered during scoping included;

    a.  Relevant issues to be considered in an ESIA
    b.  Appropriate time and space boundaries of the ESIA
    c.  Information necessary for decision-making
    d.  Significant effects and factors to be studied in detail

### 13.3.1  Alternative Sites

The scoping for environment and social impacts has been carried out for all the alternative WWTP sites considered in the Wastewater Master Plan. A summary of the findings for the alternative sites based on the scoping is presented in **Table 13.1** and **13.2** and **Figure 13.1** below and Figure **13.2** on **Page 13-4**.

**Table 13.1: Site Description – Uhuru Farm / Bofa Maweni**

| Site Name | Environment and Social Parameters | Remark |
|---|---|---|
| Uhuru Farm (Bofa / Maweni) Site | • No anticipated significant impact to natural environment<br>• No significant impact to Health and Safety of the community<br>• No significant impact to social environment, however OP 4.12 is triggered due to isolated households identified on site and the fact that the land belongs to private individuals. | • Detailed ESIA required at Detailed Design Stage<br>• Full RAP required Detailed Design Stage<br>• Site ideal WSPs from an Environment and Social perspective |

**Figure 13.1: Uhuru Farm / Bofa Maweni**



**Table 13.2: Site Description – Baobab (Hospital / Nayeni) Site**

| Site Name | Environment and Social Parameters | Remark |
|---|---|---|
| Baobab (Hospital / Nayeni Site) | • No anticipated significant impact to natural environment<br>• Significant impact to Health and Safety of the community (located within Nayeni Estate)<br>• Significant impact to social environment (Land Acquisition and Resettlement) | • Site not suitable for WSPs from an Environment and Social perspective |

**Figure 13.2 – Baobab (Hospital / Nayeni) Site**



### 13.3.2  Selected Site

In consideration of the evaluated environmental and social factors, the most suitable site for development of Wastewater Treatment Plant is Uhuru Farm Site. It presents the least significant environmental and social risks which can be mitigated by undertaking an Environment Assessment and Resettlement Action Plan.

The subsequent sub-section summaries the Environmental and Social Impact, Resettlement Impact and their proposed mitigation measure with respect to developing Wastewater Treatment Plant at the selected site and implementing the Wastewater Management Strategy in general.

### 13.4  Environment and Social Impact Scoring and Rating Criteria

In carrying out the environmental and social assessment, a standard impact rating criteria has been adopted for the evaluation of the significance of environment and social impacts associated with the proposed Project components (both during construction and operation).

The impacts have been analysed based on their severity, scope and duration as summarized in **Table 13.3** below.

**Table 13.3: Environment Impact Scoring and Rating Criteria**

| Severity of Impact | Rating | Scoring |
|---|---|---|
| Insignificant / non-harmful/less beneficial | -1/+1 | Very Low |
| Small/ Potentially harmful / Potentially beneficial | -2/+2 | Low |
| Significant / slightly harmful / significantly beneficial | -3/+3 | Medium |
| Great/ harmful / beneficial | -4/+4 | High |
| Disastrous/ extremely harmful / extremely beneficial | -5/+5 | Very high |
| **Spatial Scope of the Impact** | **Rating** | **Scoring** |
| Activity specific | -1/+1 | Very Low |
| Right of way specific | -2/+2 | Low |
| Within Project area 5km radius | -3/+3 | Medium |
| Regional / County | -4/+4 | High |
| National | -5/+5 | Very high |
| **Duration of Impact** | **Rating** | **Scoring** |
| one day to one month | -1/+1 | Very Low |
| one month to one years | -2/+2 | Low |
| Within Project construction period | -3/+3 | Medium |
| within the Project life | -4/+4 | High |
| at decommissioning | -5/+5 | Very high |

**Example of Cumulative Impact Scoring**

1. +3,+2,+5,+4, +4,+1=+4 (the weight that occurs more becomes the overall rating)
2. +2,+2,+5,+4, +4,+1=+3 (if two scores or more tie, then an average of the scores shall be adopted)

## 13.5    Positive Impacts During the Construction Phase

### 13.5.1    Creation of Employment and Business Opportunities

It is anticipated that the Project construction will create new employment opportunities in the form of skilled and unskilled labour, Suppliers and Sub-Contractors, etc.  This will reduce unemployment, improve income status of the local workers' household and increase revenue.

The Impact Rating for Creation of Employment and Business Opportunities is given in **Table 13.4** below.

**Table 13.4: Impact Rating for Creation of Employment**

| Severity of Impact | +4 |
|---|---|
| Spatial Scope of the Impact | +3 |
| Duration of Impact | +3 |
| **Overall score** | **+3** |
| **Impact Rating** | **Medium - Beneficial** |

## 13.6    Positive Impacts During Operation Phase

### 13.6.1    Reduction of Terrestrial and Marine Pollution

Once commissioned, it is expected that the Project will reduce both terrestrial and aquatic pollution caused by discharge of untreated sewage into the river channels, in this case Pemba River.  Pollution of open storm water drains and water resources within Kilifi Town due to improper disposal of wastewater will also be minimized.

The impact rating for elimination of pollution is presented in **Table 13.5** below.

**Table 13.5: Impact Rating for Elimination of Pollution**

| Severity of Impact | +5 |
|---|---|
| Spatial Scope of the Impact | +4 |
| Duration of Impact | +4 |
| **Overall score** | **+4** |
| **Impact Rating** | **High – Beneficial** |

### 13.6.2    Improved Hygiene and Sanitation in the Project Areas

Good Hygiene and Sanitation Standards are linked to provision of sanitation infrastructure. Kilifi Town will benefit from improved hygiene and sanitation from the Wastewater Management Scheme if implemented.

The impact rating for improved Hygiene and Sanitation in the Project Area is summarized in **Table 13.6** below.

**Table 13.6: Impact Rating for Improved Hygiene and Sanitation**

| Severity of Impact | +4 |
|---|---|
| Spatial Scope of the Impact | +3 |
| Duration of Impact | +4 |
| **Overall score** | **+4** |
| **Impact Rating** | **High – Beneficial** |

### 13.6.3    Increased Water Availability through Re-Use

Treated effluent from the Waste Water Treatment Plant is a source of re-charge to the water bodies. If found economically viable at a later stage, the effluent from the Waste Water

Treatment Plant can be re-used for farm irrigation and other non-potable uses.

The impact rating for increased water availability is presented in **Table 13.7** below;

**Table 13.7: Impact Rating for Increased Water Availability**

| Severity of Impact | +3 |
|---|---|
| Spatial Scope of the Impact | +3 |
| Duration of Impact | +4 |
| **Overall score** | **+3** |
| **Impact Rating** | **Medium – Beneficial** |

### 13.6.4   Reduced Cases of Water Borne Diseases

Cases of water borne disease in Kilifi Town are likely to reduce with improved sanitation infrastructure. This will effectively reduce related medical expenses among the residents with extended long term increased social productivity.

The impact rating for reduced water borne related diseases in the Project Area are summarized in **Table 13.8** below.

**Table 13.8: Impact Rating for Reduced Water Related Diseases**

| Severity of Impact | +4 |
|---|---|
| Spatial Scope of the Impact | +3 |
| Duration of Impact | +4 |
| **Overall score** | **+4** |
| **Impact Rating** | **High – Beneficial** |

### 13.6.5   Reduced Water and Sanitation Burden to Women

The socio-economic survey undertaken in the Study Area found that the burden of collecting water and solving sanitation problems in a household is mainly the responsibility of women. The same applies to caring for the sick who suffer from water related illness.  Improved sanitation system will lessen this burden and enhance family health.

The impact rating for reduced burden to women due to improved water and sanitation system is shown in **Table 13.9** below.

**Table 13.9: Impact Rating for Reduced Burden to Women**

| Severity of Impact | +3 |
|---|---|
| Spatial Scope of the Impact | +3 |
| Duration of Impact | +4 |
| **Overall score** | **+3** |
| **Impact Rating** | **Medium – Beneficial** |

### 13.6.6   Increased Land Values in the Project Area

Provision of the sanitation infrastructure to Kilifi Town will result to appreciation of land value due to improved access to proper sanitation facilities.

The impact rating for increased land values is shown in **Table 13.10** below.

**Table 13.10:  Impact Rating for Increased Land Values**

| Severity of Impact | +3 |
|---|---|
| Spatial Scope of the Impact | +3 |
| Duration of Impact | +4 |
| **Overall score** | **+3** |
| **Impact Rating** | **Medium – Beneficial** |

## 13.7    Negative Impacts and Mitigation Measures During the Construction Phase

### 13.7.1  Negative Impacts to the Biophysical Environment and Mitigation Measures

#### (i)   Destruction of Vegetation in areas covered by the Project Components

From site visit, it has been realized that most parts of the Kilifi are less vegetated except for isolated coastal vegetation. Therefore, less significant impact of the Project to vegetation is anticipated.

The impact rating for destruction of vegetation cover is shown in **Table 13.11** below**.**

**Table 13.11: Impact Scoring for Destruction of Vegetation Cover**

| Severity of Impact | -3 |
|---|---|
| Spatial Scope of the Impact | -2 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Low Negative** |

**Mitigation Measures**

- Site clearance and construction activities will be limited within the required extent to minimize destruction to vegetation cover
- Reinstatement of the Project sites to their original state once construction works are completed to allow vegetation growth
- Vegetation and trees damaged during construction to be replaced / reinstated if possible, after completion of the Works

#### (ii)  Contamination of Water Resources

The proposed Wastewater Management Scheme entails collection of wastewater within the study area of Kilifi Town, conveyance to the proposed WWTP for treatment and discharge of treated effluent to to the Indian Ocean through Kilifi Creek.

During the construction period, effluent from construction plant and equipment (oils, grease, hydro-carbonates) are potential pollutants of water resources. The effluent originates from activities such as cleaning, repair of the equipment as well as leakages during normal operation. As a result of surface run-off, these effluents will be conveyed to the Ocean through natural drains, streams and rivers resulting to contamination of water resources.

The impact rating of contamination of water resources is shown in **Table 13.12** below.

**Table 13.12: Impact Rating for Contamination of Water Resources**

| Severity of Impact | -2 |
|---|---|
| Spatial Scope of the Impact | -1 |
| Duration of Impact | -3 |
| **Overall score** | **-2** |
| **Impact Rating** | **Low – Negative** |

**Mitigation Measures**

- Risk of water resources pollution by discharges from Construction Equipment is low; however, it will be further minimized by ensuring Construction Equipment is well maintained and serviced per manufacturer's specifications to prevent oil leaks.
- Cleaning / repair of Construction Plant and Equipment to be carried out at designated yards and the Contractor to have designated storage areas for oils, fuels etc. that is protected from rain water and away from nearby surface water courses.

**(iii) Soil Erosion Resulting to Loss of Top Soil**

Site clearance, excavation and ground levelling activities during construction of the Project Components loosen the top soil and make it susceptible to erosion agents (wind and water).

The impact rating for soil erosion is shown in **Table 13.13** below.

**Table 13.13: Impact Rating for Soil Erosion**

| Severity of Impact | -2 |
|---|---|
| Spatial Scope of the Impact | -2 |
| Duration of Impact | -3 |
| **Overall score** | **-2** |
| **Impact Rating** | **Low – Negative** |

**Mitigation Measures**

The risk of soil erosion is low as the design of the sanitation infrastructure has incorporated measures to minimize this risk through provision of erosion prevention structures i.e. gabions, scour checks, etc. in areas susceptible to soil erosion such as river banks.

**(iv) Solid Wastes Pollution (Construction Activities)**

Construction activities and Contractor's Camps will generate solid wastes such as plastics, used tires, metal parts, biodegradable materials, etc. Such wastes if poorly disposed of can lead to pollution of nearby water courses and blockage of drainage and sewerage systems.

The impact rating for pollution by solid wastes is shown in **Table 13.14** below.

**Table 13.14: Impact Rating for Pollution by Solid Wastes**

| Severity of Impact | -3 |
|---|---|
| Spatial Scope of the Impact | -2 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Medium – Negative** |

**Mitigation Measures**

- Construction wastes (residual earth, debris and scrap materials) to be collected at designated points and Contractor to dispose to designated Solid Waste Dumping Sites approved by the Kilifi County Government.
- Environmental Management, Health and Safety Training Programmes to be conducted for Contractor's Staff to create awareness on proper solid wastes management

**(v) Air Pollution and Dust Generation**

Air Pollution will result from dusts and emissions from Construction Plant, Equipment and Vehicles. Dusty conditions result due to unpaved roads and tracks, exposed and non-vegetated surfaces, etc. Project borrow pits and quarries are also potential sources of dust.

Impact rating for air pollution and dust generation is shown in **Table 13.15** below.

**Table 13.15: Impact Scoring for Air Pollution and Dust Generation**

| Severity of Impact | -3 |
|---|---|
| Spatial Scope of the Impact | -2 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Medium – Negative** |

**Mitigation Measures**

- Contractor to comply with the provisions of EMCA 1999 (Air Quality Regulations 2014)
- Workers to be trained on management of air pollution from vehicles and machinery and construction machinery maintained and serviced in accordance to Manufacturer's Specifications
- Removal of vegetation to be avoided until clearance is required and exposed surfaces re-vegetated or stabilized as soon as possible
- The Contractor shall not carry out dust generating activities (excavation, handling and transport of soils) during times of strong winds
- Vehicles delivering construction materials and vehicles hauling excavated materials shall be covered to reduce spills and windblown dust
- Water sprays shall be used on all earthworks areas within 200 metres of human settlement especially during the dry season.

### 13.7.2 Negative Impacts to the Socio-Economic Environment and Mitigation Measures

#### (i) Land Acquisition and Impacts to Assets and Sources of Livelihood

The Project implementation require land acquisition for the WWTP and Pumping Stations e.g. for the WWTP at the site LR No. Mtondia MUT/237/987/08/16 Parcel Number 254, 255 and 256, which are privately owned.

This triggers application of World Bank OP 4.12, which requires that a Resettlement Action Plan (RAP) be prepared at the Detailed Design Stage.

**Table 13.16** below presents a summary of Resettlement Impacts identified for the proposed Uhuru Farm site;

**Table 13.16: Resettlement Impacts – Uhuru Farm Site**

| Site Name | Category of Loss Identified | Extent and Magnitude of Loss | Land Details |
|-----------|---------------------------|------------------------------|--------------|
| Uhuru Farm | • Loss of Land (WWTP site) <br> • Loss structures <br> • Loss of crops and trees | Land requirement approximately 30 Ha | Mtondia MUT/237/987/08/16 Parcel Number 254, 255 & 256 |

The Impact Rating for Resettlement Impacts is shown in **Table 13.17** below.

**Table 13.17: Impact Scoring for Resettlement Impacts**

| Severity of Impact | -4 |
|--------------------|----|
| Spatial Scope of the Impact | -2 |
| Duration of Impact | -3 |
| **Overall score** | **-4** |
| **Impact Rating** | **High – Negative** |

**Mitigation Measures**

- A Resettlement Action Plan (RAP) need to be prepared and implemented prior to commencement of construction activities.

#### (ii) Disruption of Public Utilities

The proposed Project will affect other public utility infrastructure including existing data cables, plot access culvers, existing water and sewerage infrastructure, access roads and storm water drainage channels. This impact will be more significant during the construction of sewers which are located along road reserves.

Impact rating for disruption of public utilities is shown in **Table 13.18** on **Page 13-10**.

**Table 13.18: Impact Rating for Disruption to Public Utilities**

| | |
|---|---|
| Severity of Impact | -3 |
| Spatial Scope of the Impact | -2 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Medium - Negative** |

**Mitigation Measures**

- Contractor to carry out piloting to locate services such as pipes and cables along the Pipeline Route before commencing excavation works.
- Relevant Services Providers and Agencies (KeNHA, KURA, KeRRA, Kenya Power, etc.) to be notified prior to commencement of Works so that any relocation works can be carried out before commencement of the pipeline construction.

**(iii) Increased Transmission of HIV/AIDS**

The Project is expected to attract new people to the Project area seeking employment during the construction period. This has the potential to increase transmission of HIV/AIDS and other sexually transmitted diseases (STDs).

Impact rating for increased transmission of HIV/AIDS is as shown in **Table 13.19** below.

**Table 13.19: Impact Rating for Increased Transmission of HIV/AIDS**

| | |
|---|---|
| Severity of Impact | -2 |
| Spatial Scope of the Impact | -3 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Medium - Negative** |

**Mitigation Measures**

- HIV/AIDS Awareness Program to be instituted and implemented as part of the Contractor's Health and Safety Management Plan to be enforced by the Supervisor. This will involve periodic HIV/AIDS Awareness Workshops for Contractor's Staff
- Access to Contractor's Workforce Camps by outsiders to be controlled
- Contractor to provide standard quality condoms to personnel on site

**13.7.3 Negative Impacts on Occupational Health and Safety and Mitigation Measures**

**(i)   Noise and Excessive Vibrations**

Noise and excessive vibrations are caused by operation of construction plant and equipment and activities during excavation and rock breaking. This impact poses a health and safety risk to the communities living in the Project area and construction workers.

Impact rating for noise and excessive vibrations is shown in **Table 13.20** below.

**Table 13.20: Impact Rating for Noise and Excessive Vibrations**

| | |
|---|---|
| Severity of Impact | -3 |
| Spatial Scope of the Impact | -1 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Medium - Negative** |

**Mitigation Measures**

- Contractor to comply with provisions of EMCA 1999 (Noise and Excessive Vibrations Regulations of 2009)
- Contractor to keep noise level within acceptable limits (60 Decibels during the day and 35 Decibels during the night) and construction activities shall, where possible, be confined to normal working hours in the residential areas
- Hospitals and other noise sensitive areas such as schools shall be notified by the Contractor at least 5 days before construction is due to commence in their vicinity
- Complaints received by the Contractor regarding noise to be recorded and communicated to the Supervising Engineer for appropriate action

**(ii)  Risk of Accidents at Work Sites**

Most accidents during construction result due to failure to use Personal Protective Equipment (PPE) by workers on site and members of the public illegally accessing the Sites; resulting to injuries or death of workers / members of the public.

Impact rating for risk of accidents at work sites is shown in **Table 13.21** below.

**Table 13.21: Impact Rating for Risk of Accidents at Work Sites**

| Severity of Impact | -4 |
|---|---|
| Spatial Scope of the Impact | -3 |
| Duration of Impact | -3 |
| **Overall score** | **-3** |
| **Impact Rating** | **Medium - Negative** |

**Mitigation Measures**

- Construction Workers and the Supervising Team to be provided with Personal Protective Equipment including gloves, gum boots, overalls and helmets. Use of PPE to be enforced by the Supervising Engineer
- Fully stocked First Aid Kits to be provided at the Sites, Camps and in all Project Vehicles
- Contractor to provide a Health and Safety Plan prior to the commencement of works to be approved by the Supervising Engineer.
- Camps and Work Sites to be fenced off and Security Guards tasked to restrict access by members of the public.

## 13.8  Negative Impacts During Operation

The Project once commissioned has the potential of triggering negative impacts associated with operation and maintenance as summarized in **Table 13.22** below.

**Table 13.22: Environment and Social Risk during Project Operation**

| Impact | Summary of Mitigation |
|---|---|
| Risk of encroachment and construction of structures on sewer wayleaves | - Mapping and installation of beacons which illustrate the width of the sewer pipeline reserve<br>- Regular inspection of the pipeline corridor for encroachment.<br>- Prosecution of encroachers as required by county by laws on way leaves and road reserves maintenance. |
| Risk of illegal connection to the sewer pipeline | - Conduct public sensitization programs on importance of not interfering with the sewer pipeline and the need to seek official sewer connection from Kilifi Water and Sanitation Company (KIMAWASCO). |
| Risk of Sewer blockage and overflows to the environment | - Awareness rising among community members not to dump solids in manholes and report any blockages to KIMAWASCO<br>- Regular cleaning of grit chambers and sewer lines to remove grease, grit and other debris that may lead to sewer backups |

| Impact | Summary of Mitigation |
|---|---|
| | • Design manhole covers to withstand anticipated loads and ensure that the covers can be readily replaced if broken to minimize entry of garbage and silt into the system<br>• Ensure sufficient hydraulic capacity to accommodate peak flows and adequate slope in gravity mains to prevent build-up of solids and hydrogen sulphide generation |
| Risk of invasion of birds, rodents, mammals and associated reptiles to sewer treatment plants | • Keep the WWTP clean to limit the attraction of birds which scavenge for insects and maggots from the ponds and sludge beds<br>• WWTP should be protected from wildlife encroachments by providing secure barriers<br>• The quality of treated effluent before discharge into the ocean will be an important parameter on the regional control of the ocean shoreline eutrophication.<br>• Continuous generation and sharing of sewage quality data on pre-scheduled monitoring programmes will be necessary |
| Risk of Vandalism of the infrastructure (Manhole covers and manhole step irons) | • Manhole covers and step irons where made of steel become prone to vandalism and pilferage<br>• Manhole covers and manhole step bars should be made of alternative materials such as high density plastic which has small scrap resell value |
| Air pollution from odour emanating from WWTP | • Plant trees especially bamboos and eco-friendly indigenous trees around the WWTP for odour control and wind breaking<br>• Ensure appropriate covering/ventilation of pre-treatment unit<br>• Ensure appropriate handling and removal of grit/grease<br>• Ensure proper sizing and alignment of the lagoons<br>• Ensure scum is appropriately disposed of or properly stabilized<br>• Ensure that the pond series have adequate water flow and aeration to reduce the potential of odour formation<br>• Construct roofs over the sludge drying beds to protect drying sludge from precipitation<br>• Appropriate disposal to reduce odour emanating from wet sludge |
| Land and Soil Contamination | • KIMAWASCO to attend to sewer bursts and overflows promptly<br>• Provide high risk areas with appropriate drainage for effective channelling of burst sewage spills;<br>• Encourage land owners along sewer lines to maintain vegetated belts along the pipeline to control any overflows flows and trap soil. This should include protection of sewers.<br>• Install Marker posts along the pipeline alignment for ease of identification and protection by the adjacent landowners |

## 13.9 Project Resettlement Impacts

This section presents Preliminary Resettlement Action Plan (RAP) for Project-Affected Persons (PAPs) in the Project Area (PA) who will be affected by the planned implementation of Project components presented in the Waste Water Master Plan for Kilifi.

The Project components involved include;

- Waste Stabilization Pond (WSP) at Uhuru Farm
- Trunk, Secondary and Tertiary Sewers
- Pumping Stations

### 13.9.1   Objectives of RAP

The RAP aims to ensure that all affected parties are compensated and assisted in restoring their livelihood.

The main objectives of the Preliminary RAP are:

(a)   To identify PAPs and their properties and determine the extent of involuntary resettlement/displacements and restricted access impacts associated with the Project implementation and put in place measures to minimise and/or mitigate such impacts;

(b)   To set out strategies for the preparation of detailed RAP and implementation of the RAP, including the process through which to acquire the necessary land and easements for the implementation of the Project activities; and

(c)   To carry out consultations with community members and other stakeholders, including PAPs, and make them aware of the project and to obtain their concerns regarding the economic and social impacts of the proposed Project and mitigation measures.

This Preliminary RAP defines the procedures and methodology for identifying the PAPs and spells out the compensation entitlements for PAPs, the socio-economic profiles of the Project areas, the legal and institutional framework that impacts on resettlement and compensation.

### 13.9.2   Guiding Legislations and Policies

The assessment identified that both community land and private land will be acquired either as easement or permanently for construction of the Project. Land acquisition will be carried out as stipulated in the Land Act 2012, Land Registration Act 2012, National Land Commission Act 2012 as well as the World Bank Operation Safeguard Policy OP 4.12 on Involuntary Resettlement as presented below;

- World Bank OP 4.12
- Land Act 2012
- Land Registration Act 2012
- Valuation Act
- National Land Commission Act
- The Constitution of Kenya

### 13.9.3   Identified Project Resettlement Impacts

In general, the assessment determined that the Project will result to the following impacts:

- Land acquisition for establishment of the proposed Projects Components
- Potential Project Impacts on people's assets and sources of livelihood
- Potential Project Impacts on the environment

A summary of preliminary Project impacts in terms of type, nature and ownership of potential assets to be affected for the Master Plan is given in **Table 13.23** below.

**Table 13.23: Project Resettlement Impacts for Master Plan Projects**

| Project Component | Category of Loss | Land Requirement (Ha) | WWTP Land Ownership |
|---|---|---|---|
| Waste Stabilization Pond (WSP) | • land acquisition required <br> • Loss residential structures <br> • Loss of crops and trees | 5 | Private Land (owner to be identified) |
| Trunk, secondary and tertiary sewer lines | • Loss business structures <br> • Loss of crops and trees | N/A | Road reserves land and river riparian land |
| Pumping Stations | • Land acquisition required <br> • Loss business structures <br> • Loss of crops and trees | 0.3 | Varied locations Public / Private land |

### 13.9.4  Eligibility for Compensation and 'Cut-Off' Date

The affected persons, irrespective of their status, are eligible to some form of assistance if they occupied the land or engaged in any livelihood income-generating activity at the affected sites before the entitlement 'cut-off date'. This date will be determined at detailed RAP stage for each of the identified Project in the Master Plan.

The following categories will be eligible for compensation under the RAP;

- People who own land at the identified sites for the Projects
- People whose houses/structures (commercial or residential) will be affected by acquisition of land for the Project.
- People who rent structures (tenants) and are doing business and whose structures are to be temporarily removed or relocated
- Mobile traders within the identified Project sites.
- People whose crops and trees will be affected by acquisition of Project or the physical project activity implementation.

### 13.9.5  Livelihood Restoration

Livelihood restoration is an important aspect in ensuring that the PAPs livelihood is totally restored even after compensation is done. In a bid to ensure that livelihoods are improved and restored to full replacement levels, the Preliminary RAP has made provisions which will be fully determined at detailed RAP stage. This will be achieved through the following:

- Determination of average monthly income and compensation for loss of income for a period of three months to cushion PAPS during transition period before source of income is restored
- Payment of compensation cash to the PAPs prior to implementation of Project activities
- Compensation for structures, crops and trees has incorporate disturbance allowance of 15% the value of structure and right of salvage
- Sensitization of PAPs on the impacts of the project to their assets / sources of livelihood and mitigation measures put in place
- Provision of ample time for affected person to remove and reconstruct structures away from the Project route and sites prior to commencement of construction work
- Implementation of a monitoring programme to ensure that the PAPs have well re-established their structures and business away from Project routes and sites
- The RAP implementation team at CWSB will ensure that the spouses of affected asset owners are included in the RAP implementation process in a bid to enhance safeguard of the family's livelihood upon compensation
- A grievance redress mechanism will be established to provide the PAPs with a system to channel their complaints and seek redress during compensation and re-establishment phase. This measure will be ensured by the GRM committees identified in this RAP
- Implementation of a Financial Management Training to be provided to the PAPs prior to disbursement of cash compensation. This Training will be outsourced by CWSB to a suitable Financial Training Organization. The Financial Training Organization will develop a suitable Training Curriculum and deliver the Training to PAPs under supervision of CWSB

### 13.9.6 Vulnerable Groups

The preliminary RAP recognizes that there are vulnerable groups among the PAPs. These are social and distinct groups of people who might suffer disproportionately or face the risk of being marginalized as a result of resettlement compensation and specifically:

      a. Female-and child-headed households
      b. Disabled household heads
      c. Households where the head is unemployed
      d. Households headed by elderly persons with no means of support.

The list of properties and owners (PAPs) will be identified at detailed RAP stage. These categories of PAPs will be entitled to adequate compensation as presented in the Entitlement Matrix on **Table 13.24** on **Page 13-15 to Page 13-18**.

**Table 13.24: Entitlement Matrix**

| | Type of Loss | Unit of Entitlement Persons | Entitlements |
|---|---|---|---|
| **A.** | **Loss of Residential/Commercial/Industrial Land** | | |
| 1 | Partial loss of land but residual is viable | (a)Titleholder | • 100% Cash compensation for loss at replacement cost<br>• 15% cash top up in compulsory acquisition<br>• Cash compensation for standing assets<br>• Administrative charges, title fees, or other legal transaction costs<br>• Money Management training |
| | | (b)Tenant<br><br>(c) Lease holder | • Cash compensation for standing assets<br>• Administrative charges or other legal transaction costs<br>• One month notice to vacate<br>• Money Management training |
| | | d) Informal Settlers | • Cash compensation for standing assets<br>• One month notice to vacate<br>• Money Management training |
| 2 | Entire loss of land or partial loss where residual is not viable | (a)owners | • 100% Cash compensation for entire land holding at replacement cost<br>• Replacement cost for standing assets erected by the Land Owner<br>• 15% cash top-up in compulsory acquisition<br>• Administrative charges, title fees, or other legal transaction costs<br>• Money Management training |
| | | (b) Tenant (either residential or business)<br>(c)Lease holders | • Replacement cost for standing assets<br>• Administrative charges or other legal transaction costs for registered leases<br>• One month notice to vacate<br>• Money Management training<br>• Relocation assistance |
| | | (d) Informal Settler | • Replacement cost for standing assets<br>• Possibility of land grant where possible alongside relocation and assistance with livelihood restoration<br>• One month notice to vacate<br>• Money Management training |
| **B.** | **Loss of Structures** | | |
| 3 | Partial loss but residual viable | (a) Legal User with valid titles | • Cash compensation at replacement cost for affected portion calculated on market value without depreciation<br>• Repair costs for unaffected structure or cash equivalent to 25% of the compensation<br>• Right to salvage material plus relocation costs. |
| | | (b) Owner without titles | • Cash compensation at replacement cost for affected portion based on market value without depreciation |

| | Type of Loss | Unit of Entitlement Persons | Entitlements |
|---|---|---|---|
| | | | • Repair costs for unaffected structure or cash equivalent to 25% of the compensation<br>• Right to salvage material plus relocation costs |
| | | (c) Informal user of building | • Cash compensation at replacement cost for affected portion based on market value without factoring depreciation<br>• Repair costs for unaffected structure at 25% compensation<br>• Right to salvage material plus relocation costs<br>• Where possible suggest and/or provide alternative business areas |
| 4 | Fully affected/part affected and remaining structure is non-viable | (a) Land owner with valid title | • Cash compensation at replacement cost of the affected unit based in market value without depreciation plus a house building allowance at 25% of compensation<br>• Right to salvage materials without deduction from the compensation package<br>• One month notice to vacate<br>• Relocation assistance |
| | | (b) Tenant/Lease Holder | • Cash compensation for remaining lease/deposits<br>• Right to salvage materials<br>• One month notice to vacate<br>• Relocation assistance |
| **C.** | **Movable / Mobile structures** | | |
| 5 | | Kiosks or Stalls | • Cash Compensation of comparable replacement sites<br>• Cash Compensation of replacing improvements (such as foundations), and relocation expenses or other transaction costs. |
| **D.** | **Loss of Crops and Trees** | | |
| 6 | Trees and crops | Trees and crops owners | • Cash compensation for lost trees and crops at full replacement cost valued at market rate<br>• Allowed adequate time to harvest the crop and trees.<br>• 3-month notice to the PAPs of intention to use the site |
| **E.** | **Loss of Business / Income** | | |
| | | Business operators | • Cash compensation based on a calculated average loss of income over an appropriate period (normally 3 months)<br>• Livelihood restoration measures as identified in earlier sections |
| | | Landlords | • Cash compensation based on a calculated average loss of income over an appropriate period (3 months) |
| | | Employees | • Compensation as per national legal provisions (formal employees)<br>• Informal employees: one month minimum wage<br>• Casual, day to day labourers will receive advance notice that businesses will be removed |
| **F.** | **Loss of Community Proprietary Resources** | Local Community | • In kind replacement for affected community resources/property |

| | Type of Loss | Unit of Entitlement Persons | Entitlements |
|---|---|---|---|
| **G.** | **Assistance to Vulnerable Groups** | Vulnerable Groups | • CWSB to consider other assistance over and above compensation package to cushion them against impact.  To be treated on merit basis |
| **H.** | **Graves** | Individual graves | • Negotiated reimbursement for translocation costs including option for physical translocation |
| | | Communal graveyards | • Negotiation of available options |

### 13.9.7  Grievance Management

The Project provides for simple and accessible extra judicial mechanism for managing grievance and disputes based on explanation and mediation by third parties. Each of the affected parties will be able to trigger this mechanism while still being able to resort to the judicial system

- The Grievance management provides for two tiers of amicable review and settlement, with the first tier at the site level[1]
- The second level will integrate a mediation committee in case the grievance cannot be solved at first level.
- Finally, there will be an option for each of the complainant to resort to the Court of Law (third level) in case there is no resolution of the grievance with the mechanism

Detailed Grievance redress mechanism is provided in the Preliminary RAP Report prepared as a separate assessment under this Consultancy.

### 13.9.8  RAP Implementation Arrangements

All PAPs will be compensated before their structures are demolished, implying that compensation will be paid before project works start at a specific site/in a specific area as per the contractor's work schedule. Coast Water Services Board (CWSB) will be the lead agency in the RAP implementation and will work together with the County Government of Kilifi and The National Lands Commission (NLC) to implement the RAP.

In this Project, CWSB will establish a RAP Implementation Unit (RIU)), to implement this RAP. The unit will be responsible for ensuring that PAPs promptly access their compensation entitlements and that their livelihoods are restored after resettlement. The RAP implementation team will be responsible for:

- Liaison with National Lands Commission (NLC) on matters related to RAP implementation
- Delivery of the RAP compensation and rehabilitation measures to identified PAPS

The RAP Implementation Team and NLC will develop the schedule for the implementation of RAP activities which will include:

- Target dates for the start and completion of compensation payments
- Timetables for and the place of compensation payments
- Target dates for fulfilling the prerequisites for compensation payments and other legal requirements by PAPs
- The time table for special assistance to vulnerable groups
- Dates for vacant possession of the acquired land from the PAPs (this date must be after the payment of all compensation)
- The link between the RAP activities to the implementation of the overall sub-project components

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[1]A site in this context implies areas where the PAPs are concentrated under various Project components.

### 13.9.9  RAP Monitoring and Evaluation

The purpose of monitoring and evaluation is to report on the effectiveness of the implementation of the RAP and the outcomes and impact of compensation on the PAPs in relation to the purpose and goals of the RAP. The general objective of the M&E system is to provide a basis for assessing the overall success and effectiveness of the implementation of the resettlement and compensation processes and measures.

Several Objectively Verifiable Indicators (OVIs) will be used to monitor the impacts of the compensation and resettlement activities. These indicators will be targeted at quantitatively measuring the physical and socio-economic status of the PAPs to determine and guide improvement in their social wellbeing.

The M&E will be undertaken at two levels:

- Internal monitoring: undertaken regularly by the RIU/Monitoring Officer
- External evaluations (or end-time of RAP implementation): Evaluations will be undertaken by an independent consulting firm hired by CWSB. Evaluation will be necessary to ascertain whether the livelihood and income restoration goals and objectives have been realised

Details of RAP monitoring indicators during and after Compensation Payments is presented in **Table 13.25** below.

**Table 13.25: Monitoring Indictors During and After Compensation Payments**

| Resettlement Compensation Payment Period | Post-resettlement Compensation Payment Period |
|---|---|
| <ul><li>Number of PAPs compensated</li><li>Number of PAPs who have acquired legal papers to new property</li><li>Number of PAPs who have restored their livelihood enterprises</li><li>Number of PAPs who have registered grievances with the GO</li><li>Number of PAPs whose grievances have been resolved</li><li>Number of vulnerable PAPs or groups identified and assisted during compensation payments</li></ul> | <ul><li>Number of PAPs with successfully restored livelihoods and assets,</li><li>Number of PAPs who have maintained social and cultural ties,</li><li>No of PAPs whose grievances have been resolved or otherwise,</li><li>Number of vulnerable groups assisted and restored livelihood enterprise and assets.</li></ul> |

Detailed RAP process has been provided in a separate Report presented as **D8: Preliminary Environmental and Social Impact Assessment (ESIA) & Preliminary Resettlement Action Plan (RAP) for the Preferred Development Strategy.**

## 14.0 ASSETS MANAGEMENT PLAN

### 14.1 Introduction to Asset Management Planning

This Chapter describes the purpose and requirements of an Asset Management Plan for Wastewater Management Infrastructure based on current international best practice that is applicable to CWSB and KIMAWASCO.

Asset Management is described as:
 "*The combination of management, financial, economic, engineering and other practices, applied to physical assets with the objective of providing the required level of service in the most cost effective manner*".

It can also be described as: "maintaining a desired level of service provided by assets at the lowest life cycle cost."  Lowest lifecycle cost refers to the best appropriate cost for rehabilitating, repairing or replacing an asset. Asset Management is implemented through an asset management programme that usually includes a living document in a written Asset Management Plan (AMP). In summary, an AMP identifies the assets that are owned by the entity, presents the whole life cost of managing those assets to a specified level of service and allows the entity to more effectively meet its objectives.

The challenges faced by a Water Services Provider include:
- Determining the best (or optimal) time to rehabilitate / repair aging assets
- Increasing demand for services
- Overcoming resistance to increasing tariffs
- Diminishing resources
- Rising expectations of customers/ consumers
- Increasingly stringent regulatory requirements
- Responding to emergencies due to asset failure
- Protecting assets

The benefits that result from the practice of Asset Management Plan are:
- Prolonged asset life and aid in the rehabilitation/ replacement decisions through efficient, focussed and planned operation and maintenance
- Meeting consumer demands with a focus on system sustainability
- Setting tariff rates based on sound operational and financial planning
- Budgeting focused on activities critical to sustained performance
- Meeting service expectations and regulatory requirements
- Improving response to emergencies
- Improving security and safety of assets

There are five core aspects that need to be considered in implementing asset management. These aspects are illustrated in **Figure 15.1** on **Page 15-2.**
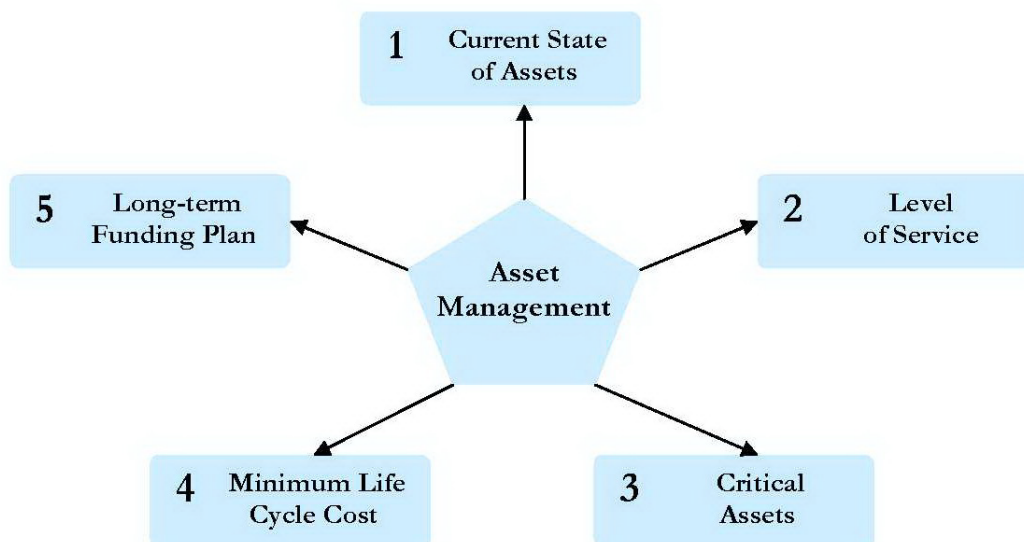
**Figure 14.1: Core Aspects of Asset Management Framework**

This framework covers all the major activities associated with asset management and can be implemented with a level of sophistication applicable to any given Wastewater Management Scheme and situation. These five core framework aspects provide the foundation for asset management.

## 14.2 Asset Inventory

The first step in Asset Management is having an inventory of assets, knowing their current state and remaining useful life. Asset inventories need to be regularly updated to reflect on the status at the time and allow for assets that are rehabilitated, repaired, added or removed from service. An Asset Inventory includes information such as: ownership, location, age/ condition, useful life and value (original cost, depreciated value and replacement value) with assets grouped and subdivided into components and elements with similar base lives. Each component or element should be allocated a unique Identity (ID) in the Asset Inventory.

International best practices on Asset Inventory include:

- Recording the details and physical location of each asset in the asset database that is categorised in a manner which can be easily searched and manipulated e.g. by type, location, condition etc.
- Mapping the system with spatial data stored in a GIS with multiple levels and layers showing the different components
- Developing a condition assessment and rating system for all assets
- Assessing the remaining useful life of assets through projected useful life tables and asset decay curves, and determining asset values and replacement costs.

## 14.3 Levels of Service

Knowing the required level of "sustainable" service helps in the implementation of an Asset Management Programme and to communicate the AMP objectives with stakeholders. It is a defined service standard driven by legislation and regulation and customer expectations and against which service performance can be measured. Quality, reliability and environmental standards are all elements that define the level of service and associated performance goals for a sanitation system, both short-term and long- term.

Defining level of service requirements can be carried out based on the use of information about customer demand, from KIMAWASCO and CWSB reports and stakeholders involved in the service provision and consumption.

The sustainable level of service needs to be updated periodically to account for changes due to future growth in supply and demand, regulatory requirements and technology improvements.

Questions that need to be answered in determining the level of service cover include:
- What level do stakeholders and customers demand?
- What are the regulatory needs of the environmental agencies?
- What is the actual system performance?
- What are the physical capabilities of the assets?

Best practices undertaken in addressing the above questions include:
- Analysing current and anticipated customer demand and satisfaction with the system
- Allowing for the current and anticipated regulatory requirements
- Writing and communicating to the public, a level of service "Agreement" that sets out the systems performance
- Using level of service standards to track system performance over time

## 14.4    Critical Assets

It is necessary to determine which assets are critical to the sustainable performance of the system.  Because assets fail, how are the consequences of failure best managed? Not every asset presents the same risk of failure, or is equally critical to the Wastewater Management Scheme performance. Critical assets are those that are classified as having a high risk of failing (through being old, in poor condition etc.) and which have major consequences if they do fail (major expense, system failure, safety concerns etc.). This type of analysis is also carried out in the vulnerability assessment.

Aspects for determining critical assets threshold are covered by addressing the following concerns:
- How can assets fail
- How do assets fail
- What are the likelihoods (probabilities) and consequences of asset failure
- What is the cost of repair or replacement
- What are the other costs (social, environmental etc.) associated with asset failure

Best practices in the analysis of critical assets include:
- Listing assets in the inventory in accordance to how crucial they are to system operations
- Conducting a failure analysis root cause analysis, failure mode analysis
- Analysing failure risk and consequences
- Using asset decay curves to determine their economic life
- Reviewing and updating the systems vulnerability assessment

## 14.5    Asset Life Cycle Costs

Asset Management enables a system to determine the lowest cost options for providing the highest level of service over time. Typically for Utility Companies (WSPs) responsible for the wastewater management, the expenses for operation and maintenance, personnel and capital budget make up around 85% of annual expenses. An appropriate Asset Management Programme helps to make risk-based decisions for choosing the priority projects based on a time schedule and sound reasons.

Important issues to be addressed include:

- What alternative strategies exist for managing O&M, personnel and capital budget accounts?
- What strategies are most feasible?
- What are the costs of rehabilitation, repair and replacement for critical assets?

Best practices include:

- Applying predictive maintenance rather than reactive maintenance
- Knowing the costs and benefits of rehabilitation compared to replacement
- Applying lifecycle cost analysis, especially for critical assets
- Allocating resources based on asset conditions
- Analysing the cause of asset failure to develop specific response plans

Lifecycle Asset Management focuses on management and strategies considering all relevant economic and physical consequences from initial planning through to disposal, as are depicted in Figure **15.2** below.



**Figure 14.2: Life Cycle Asset Management**

### 14.6    Long-Term Funding and Classifying Expenditure

Sound financial decisions and developing an effective long-term funding strategy are critical to the implementation of an AMP. Knowing the full financial costs and revenues generated by the Wastewater Management Scheme enables managers to produce reliable forecasts and budgets, which helps to decide changes needed for the long-term funding strategy to meet the AMP. The funding plan shows the relative magnitude of the different expenditure categories, which are usually broadly divided into operating and capital expenditure.

Annual expenditure can further be classified into the following categories:

### 14.6.1   Operational Expenditure

This is expenditure associated with the day to day running of the assets. They are those that generally consume resources such as manpower, energy and materials.

### 14.6.2   Maintenance Expenditure

This is expenditure required for maintaining an asset to achieve its design life. Maintenance expenditure can be planned (proactive/predictive) or unplanned (reactive). This cost excludes asset rehabilitation or renewal. The application of regular and timely maintenance can have a significant effect on the performance and life of the asset.

### 14.6.2.1    Renewal Expenditure

Expenditure associated with works for the rehabilitation or replacement of existing assets with those of equivalent capacity or performance. Having provisions for this type of expenditure is crucial for all facilities including new ones and is typically planned for 5 – 10 years after the construction or installation of the assets.

Deterioration curves or asset decay curves are used to calculate the life of an asset and decide the appropriate time for asset renewal instead of spending increasing amounts on annual maintenance and repair.

### 14.6.2.2    Capital Expenditure

Expenditure used to create new assets, or to increase the capacity of existing assets beyond their original design capacity or service is classified as capital expenditure.

### 14.7    Funding Plan

The preparation of accurate budgets and forecasts in a funding plan show whether the entity has sufficient funding to maintain the assets to the required level of service, and ultimately are the tariffs sufficient to meet the long-term needs.

Strategies to consider to meet this objective include:
* Revising the tariff structure
* Funding a dedicated asset renewal reserve fund from current revenue to provide for future needs (creating an asset annuity)
* Financing asset rehabilitation, repair and replacement through borrowing or other financial assistance.

### 14.8    Asset Management Plan Implementation

An AMP is a "living document" that constantly requires updating and revision by managers to accommodate changes to the asset inventory resulting from the rehabilitation, replacement and addition of assets. Deficiencies in AMP can be detailed in the improvement programme through its updates.

Management and strategic sectors of the entity is as shown in the **Figure 14.3** on **Page 14-6**.

**Figure 14.3: Where the AMP Fits In**

### 14.9    CWSB Asset Management Plan Situation

Currently CWSB and KIMAWASCO do not have a comprehensive Asset Management Plan in place along the lines of the AMP structure described above. There is thus an urgent need to prepare an Asset Management Plan for KIMAWASCO with respect to water and sanitation services

The main aspects that need to be addressed while developing an AMP include;

- Define sustainable levels of service to customers
- More specifically determine critical assets and asset life cycle costs
- Define O&M, asset rehabilitation and renewal costs with a long-term funding strategy for the AMP
- Define the resources needed for implementing the AMP in terms of manpower, equipment, spare parts, training, outsourcing, etc.
- Define the process of incorporating the AMP into the business plan and operational procedures of CWSB and KIMAWASCO and procedures for the regular updating and modification of the AMP.

## 15.0     RISK MANAGEMENT

### 15.1     Introduction

Risk management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. Risk management's objective is to assure uncertainty does not deflect the endeavour from the project goals.

Risk management in Water Supply and Sanitation Systems is crucial.

Water is a finite and vulnerable environmental resource essential for life, social and economic good. The allocation of scarce water resources among competing uses has fundamental effects on the ecosystems and national economic development in terms of employment and the generation and distribution of income and poverty alleviation. Such policies can also have a significant impact on land use planning and the movement of population from rural to urban areas. The access to suitable amounts of water for basic human needs is therefore essential to be incorporated in the formulation and implementation of economic policies for resource development and allocation. Decreasing availability of usable water supplies, coupled with increases in demand can potentially lead to the inefficient and unsustainable use of water resources with significant economic, social, and environmental consequences.

Fresh water resources are clearly of critical importance, for urban and rural areas, for households and industry, for agricultural crops and livestock, for human health, for the environment, and for the maintenance of the environmental services upon which these depend. Potentially conflicting demands for fresh water supplies may threaten the sustainability of this essential resource, with significant economic, social, and environmental consequences. Decreasing availability of usable water supplies, coupled with increases in demand can potentially lead to the inefficient and unsustainable use of water resources with significant economic, social, and environmental consequences.

Wastewater handling, treatment, disposal and re-use (where applicable) is important in determining the quality of the environment, water resources and public health.

Therefore, the environment and water natural resources should be safeguarded from all risks including monitoring the quality of effluent from Wastewater Treatment Plants which is normally discharged into natural water courses.

A risk is considered as an uncertain event or condition that, if or when it occurs, has a positive or negative effect on a project's objectives or outcome. Risks are inevitable and a component of any Project. Project managers should regularly assess risks as standard practice and develop or modify plans to address them.

The active Project level risk management plans should include an analysis of potential risks, including those with both high and low impact, as well as proposed mitigation strategies to help in counteracting negative consequences should problems arise.

**Risk Management Plans should be periodically reviewed (preferably every 5 years, if not more frequently) by the Project team to avoid having the analysis becoming stale and not reflective of actual potential Project risks**. In practice, the levels of risk involved in a specific course of action are compared to expected benefits to provide evidence for decision making.

Hazards and risks can be defined as shown in **Table 15-1 on Page 15-2.**

**Table 15-1: Definition of Project Hazards and Risks**

| | |
|---|---|
| *Hazard* | A situation or biological, chemical or physical agent that may lead to harm or cause adverse effects. |
| *Risk* | The potential consequence(s) of a hazard combined with their likelihoods/probabilities. The likelihood or probability of an adverse outcome or event. |
| *Risk Assessment* | The process of evaluating the consequences of hazards and their likelihoods or probabilities. For example, the failure of a technology may result in economic loss and associated risks. Environmental Risk Assessment is a process that evaluates the likelihood or probability that adverse effects may occur to environmental functions, as a result of human activities. Risk assessment provides a mechanism for communicating forecasted risks associated with decisions to the public and the stakeholders. |
| *Risk Management* | The process of appraising options for responding to risk and deciding which to implement. Risk management require periodic /continual re-assessment. |
| *Environmental Value* | An aspect of the environment that is important because of its ecological, economic or social significance to an ecosystem, the potential consequences of its loss, and/or its economic or social importance, including for example the ability of the environment to support agriculture, and to support tourism, or the human health hazards associated with deterioration in environmental services. |

Risks are often complex and may derive from a variety of factors, including uncertainty in financial markets, project or business failures, legal liabilities, credit risk, accidents, and natural causes or disasters. Importantly, risks may also derive from unintended or unrecognised consequences of developments associated with individual projects, not necessarily directly connected to the programme under consideration, and from the cumulative impacts of a variety.

Assessing a risk involves an analysis of the consequences and likelihood of a potential hazard being realised. In decision-making, low-consequence or low-probability risks are typically perceived as acceptable and therefore only require monitoring. In contrast, high-consequence or high-probability risks are perceived as unacceptable and a strategy is required to manage the risk.

A strategy would include structured risk assessment to better understand the features that contribute most to the risk, and to assist with the development of counter measures. In the long-term, education and training in risk assessment and management should be considered for managers dealing with the wastewater management sectors. Furthermore, the precautionary principle should be adopted when considering and assessing risks, particularly where hazards have long environmental lifetimes or accumulative or irreversible consequences.

In the wake of the recent global economic problems, risk management is increasingly seen as an important executive-level issue and a process that needs to be incorporated in day-to-day decision making for long-term profitability and competitive advantage.

In general, risk management is considered to include the following elements:
1. Identify, categorise and assess potential threats.
2. Assess the vulnerability of critical components or assets to specific threats or to combinations of different threats.
3. Determine the risk and consequences of specific threats.
4. Identify mechanisms whereby those risks may be reduced.
5. Prioritise risk reduction measures, and include regular reviews of all threats as an integral component of programme management, ensuring that risk management is dynamic and responsive to change.

Potential hazards or risks can be categorised as either environmental or economic risks even though inevitable overlaps and linkages exist.

### 15.2   Environmental Risks

A range of potential environmental risks are expected in the construction and operation phases of the Wastewater Management Scheme such as from the effluent discharge into the natural water courses from the proposed Wastewater Treatment Plants.

The expected environmental and socio-economic impacts result from:
  a. Resettlement and compensation,
  b. Construction of Sewerage System (Sewers & Sewage Pumping Stations),
  c. Construction of Wastewater Treatment Plants,
  d. Operation of the Constructed Sanitation Systems.

Potential categories of risks include:
  - Changes in precipitation and temperature as a result of climate change
  - Hazards resulting from construction of the project components. Risk management procedures need to be incorporated in the detailed designs and operating procedures.
  - Discharge of inadequately treated effluent to natural water course may result to increased health risks for downstream communities or households.
  - Changes in local groundwater regime as a result of increased downstream flows after discharge of treated effluent.
  - Hazards and risks encountered during the operation of the sewerage system.

Environmental impacts resulting from construction are considered as short-term impacts and can be managed with the adoption of recommended mitigation measures.

### 15.2.1   Climate Change

Global climate is predicted to change substantially, with changes in temperature, precipitation and frequency of storms, and with subsequent effects on hydrology especially in the drier areas. A global rapid rise in temperatures in the likely range of 1.1 to 6.4°C is expected. Precipitation patterns are expected to change significantly, and extreme weather events (severe storms, floods, droughts, and heat waves) are expected to become more intense and frequent. From the sanitation (public health) and environment (water resources) perspective, the increased incidence of drought periods represents a potential critical risk.

Agricultural output is predicted to be impacted by increased temperatures and changes in precipitation and runoff. It is considered that many countries in Africa may suffer productivity losses of more than 25 percent (World Bank, 2011)[2]. Such losses are projected to be acute in the Sahel, the Horn of Africa, and in East and South-West Africa – areas that are projected to experience significant decreases in precipitation and increases in temperature. Further work focussed on Kenya also confirms that global warming will have adverse effects on agriculture (Kabubo-Mariara and Karanja, 2007)[3]. Thus, the ability to provide water for downstream environments and for irrigation purposes is likely to be of increasing importance, especially when coupled with the increasing food requirements of an increasing urban population.

Most models confirm projected changes in precipitation and temperature. Whilst the actual extent of changes in precipitation are currently uncertain, models do indicate that changes will occur. This will have inevitable implications for water and food security.

The risks from climate change can therefore be summarized as follows:

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[2] World Bank (2011). *Africa's Water Resources in a Changing - Climate: Toward an Operational Perspective. Summary Report.* Africa Region, Sustainable Development Department, The World Bank.

[3] Kabubo-Mariara, J. and Karanja, F.K. (2007). *The Economic Impact of Climate Change on Kenyan Crop Agriculture: A Ricardian Approach*. World Bank, Policy Research Working Paper 4334.

- Most parts of East Africa are projected to experience an increase in consecutive dry days.
- There will be an increase in temperatures.
- Water demands are expected to increase. Crop water requirements are expected to be higher for both rain-fed and irrigated crops as temperatures rise. Similarly, livestock are likely to require more water.
- Water-related public health could also be compromised by climate change. Hydrologic and temperature change may modify the natural habitat boundaries of disease vectors such as mosquitoes, and other water borne diseases.

Given the difficulties of averting global warming, adaptation to climate change is considered essential to counter the expected impacts of long-term climate change. Improved management and conservation of available water resources, protection of the water sources from potential pollutants, water harvesting and recycling of waste water are likely to play important roles.

Risk Management procedures need to include a regular assessment of the current climatic situation and water and sanitation related issues (public health).

### 15.2.2    Risks from Construction

Potential negative impacts expected from construction of the project components, are detailed in Chapter 13 of this Report (Preliminary Environemental Impact and Resettlement Action Plan).

In general, the impacts related to such construction activities are minor, can be understood and planned for and mitigated against. The major risks would therefore result from pre-construction phase and construction phase environmental management plans not being fully prepared in advance and not being followed and activities monitored in detail.

An important component of risk management in the pre-construction phase will be to set up a series of important long-term monitoring systems that will provide the important information required during the construction phase and during the subsequent operational phase.

At construction, the disposal of excavated material represents a potential hazard if not planned and carried out to result in minimal social, economic and environmental impact. It is recommended that instead of considering the excavated material as "spoil" requiring disposal, it should be used as raw material for a range of activities such as road repair and construction, and for use as building material, including the making of bricks for buildings.

### 15.2.3    Public Health Risks

Public health depends on factors including the quality / quantity of water supply and sanitation systems adopted in an area. Proper sanitation entails safe handling of wastewater and proper disposal of the treated effluent and sludge.

The quality of the raw water in potential water resources should be good enough to produce domestic water supplies of a safe and acceptable standard when treated. These sources should be consistent in terms of quantity and quality. In many cases, it is cheaper to protect the water resources from pollution than to provide requisite treatment after contamination to ensure achieve acceptable standards. Contaminated and poorly managed water resources contain chemical, microbiological or radiological hazards which are health hazard. One of the major risks of Water Resources is unsafe disposal of Wastewater.

The preventive measures that should be incorporated in risk management procedures include:

- Regular and comprehensive monitoring, to decide if and where contamination of the water is occurring especially when contamination of the water sources is most likely. Ideally, monitoring should be 200m downstream of wastewater effluent discharge point and 200m upstream.

- Proper operation and maintenance of the Waste Water Management Schemes to ensure proper conveyance and treatment of sewage including safe disposal of sludge

- Detailed knowledge of where the catchment (surface water) or re-charge zones (groundwater) of the water sources are, and the nature of the land and all the land use and/or land cover in these areas.

- Identifying protection zones for the sources, so that possible sources of contamination that require to be managed can be identified. This could for example, include the legal establishment of a series of Nitrate Vulnerable Zones (NVZs) within the watersheds.

As an integral component of risk management procedures, water quality data will need to be analysed and made available on a regular basis to all authorities involved with the management of these water resources and related issues.

### 15.2.4 Operational Hazards

Several hazards are inevitable during the operation of the Wastewater Management Scheme System such as:
- Blockages of sewers
- Sewer leakages and bursts; leading to ground infiltration
- Microbiological contamination of water sources and natural water courses from raw sewage or unpolished effluents
- Contamination of drainage channels and downstream water sources as a result of poorly or inadequately treated wastewater.

Risk management plans will need to take account of such operational hazards and incorporate risk reduction strategies.

### 15.3 Economic Risks

The use of pricing policies and other economic instruments are essential for the effective and equitable allocation of resource considering social and economic criteria as well as basic human needs. Economic evaluations need to consider positive and negative impacts on health, human and ecosystems. Inadequate economic policies have often contributed to the poor performance of wastewater utilities thus decreasing their ability to attract financial resources from the public and private sector as well as the international community.

While the public sector has traditionally played a major role in financing wastewater utilities development, there is an increasing recognition of the need to involve other stakeholders (private sector and community based organisations) for financial sustainability.

Financial support for the collection, processing and dissemination of timely, reliable and demand-oriented information is essential to the effective management of Wastewater Management Schemes.

### 15.3.1 Multicriteria Evaluation and Risk Analysis of Proposed Investment Scenarios

The Least Cost Analysis for the economic evaluation of alternative schemes of satisfying the sanitation needs of Kilifi Town up to year 2040, considered the capital and operational costs and their investment schedules.

The Least Cost Analysis determined the most economically efficient means of providing Wastewater Management Scheme to meet the projected demand, through a normalisation process allowing for the options different configurations, to show the Average Incremental cost of $BOD_5$ Removal (AIC) for each option expressed as US\$/m$^3$ of $BOD_5$ removed. Sensitivity analysis to test the effect of changes in the key parameters – capital costs, O&M costs, and discount rate was also carried out.

Following the Least Cost Analysis, a Multicriteria Analysis was carried out (***See Chapter 9 of this Report***) considering six key sustainability issues taking account of natural resources, economic performance, technical issues, environmental issues and social sustainability. Each aspect was scored and weighed according to its importance and the overall score used to determine the best option and strategy.

The Multicriteria Analysis allowed for other factors affecting the risk and sustainability of the development option that were not fully reflected in the economic Least Cost Analysis which uses the monetised capital and O&M costs.  Risks were accommodated in the Multicriteria Analysis by considering several factors, particularly on the operation and maintenance, schemes technical complexity and number of management entities involved; susceptibility to prioritisation and; multiplicity of the Wastewater Treatment Plant (Phasing).

The results of the Multicriteria Analysis reflect the preferred option and strategy for determining a Wastewater Management Scheme that is best suited to manage the potential risks.

### 15.3.2     Key Issues and Recommended Actions

a.  Wastewater Management Schemes must be integrated into the national economy, recognising it as a social and economic good, vital for ecosystem functioning and applying economic instruments in its management. As such, economic policies must consider "intangibles" such as social and environmental values of dealing with wastewater as well as the special conditions in non-monetary sector economies.

b.  Actions should be oriented towards applying demand based management approach taking into account the notion of users' willingness and ability to pay. Resources must help in the collection, dissemination and transfer of international experiences in economic evaluation and financial management of Wastewater Schemes. Where possible, support should be provided to strengthen private sector, community based participation as well as the development of appropriate and low cost technologies. Also, assistance should continue in favour of public institutions in improving their role.

c.  Efficiency, transparency and accountability are keys to sustainable financial management of Wastewater Management schemes. For these, information should be made public including; performance indicators, procurement procedures, pricing policies and components, cost estimates and revenues. Determination and allocation of subsidies, cross-subsidies, and charges should be transparent in order to maintain confidence and improve investment revenues in the sector.  Instruments such as auditing could help achieve this goal.

d.  Integrated Wastewater Management Schemes requires closed partnership between public and private sectors. As such, a clear definition and distinction should be made of the role of both central and county governments, the private sector and other stakeholders, where appropriate to local situations. This is expected to create more conducive institutional and legal environment for private sector investment and the emergence of local water service providers. Particular attention has to be given to financial and economic risk assessment.

e.  Regardless of policies, financial sustainability is a prerequisite for sustainable integrated Wastewater Management Schemes. Therefore, it is a necessity to facilitate a gradual transition towards full cost recovery, criteria for financial burden sharing and the development of financial and regulatory instruments. Also, measures needed include adapted financial policies for the poor and rural areas who might not have access to the water-borne sanitation system when carrying tariff studies. Emphasis should be placed on participation of users, training of local entrepreneurs and the diversification of sources of funding. Furthermore, a strong link should be made with the de-centralisation process.

f. At the same time, it is important to ensure adequate financing of the Wastewater Management Schemes. Related issues in this case concern the adequacy of absorptive capacity and availability of financial resources within the sector, the lack of political awareness and will to implement strategies aimed at recovering costs as well as the requirements of external funding sources which limit the flows of resources to the sector. Thus, actions should be aimed at improving donor-recipient dialogue on financing, the creation of national fund for financial resources mobilisation and allocation in the sanitation sector. The international community and Governments (donors and recipients alike) should be urged to maintain and be encouraged to increase their assistance to the water resources sector in a predictable manner and targeted to solve specific problems. Value can be added by improving communication and co-operation among sources of financing as well as the mobilisation of largely untapped community financing resources and through the provision of credit mechanisms which foster self-help efforts by individuals. This includes the mobilisation of innovative source of funding.

g. The frequency of extreme events has increased in recent decades. Therefore, provision should be made for economic costs analysis of these events and for the management of Wastewater Schemes.

h. In a broader perspective, several priority activities should be financed including institutional and capacity building, integrated wastewater planning and management. Particularly, local support should be provided for sustainable solutions to communities, associations, local authorities and emerging local private sector.

i. Finally, financial resources can be best attracted to the sector when efforts are made to increase financial accountability and to reduce cost in particular. For this, specific actions could include restructuring of existing institutions, improving existing management through demand management, promoting competition in service provision, data collection and creating financial incentives, participation as well as the use of low cost technologies.

### 15.3.3   Priority Areas in Need of Financing

Areas in need of financing are grouped into the following divides:

- Institutional capacity building/support to policy and legislation
- Integrated wastewater Management
- Data collection, monitoring and integrated information management systems
- Local support for sustainable solutions to communities, associations, local authorities and emerging local private sector
- Investment to areas without access to basic needs

### 15.3.4   Strategies / Action for Cost Reduction

Several strategies and actions are recommended to address economic and financial issues related to Wastewater Management Schemes. Such measures include:

- Restructuring of existing institutions to reduce cost
- Improving existing management such as demand management/leak reduction
- Promoting competition in service provision
- Improving existing data collection network
- Provision of financial incentives e.g. tax exemption for equipment and to private sector;
- Investing in under privileged areas
- Reliance on low cost systems and appropriate technologies including indigenous technologies
- Increasing accountability in system management

### 15.4    Risk Management Plan

An important component of the risk management will be the establishment of a set of systems for monitoring and recording relevant information.

General Risk Management Plan for Identified Environment and Social Risks are given in **Table 16.2** below

**Table 6.16: Identified Environment and Social Risks and Mitigation Measures**

| ACTIVITY | PARAMETER | MITIGATION MEASURES CHECKLIST |
|---|---|---|
| **0**. General Conditions | Notification and Worker Safety | (a) The local construction and environment inspectorates and communities be notified of upcoming activities<br>(b) The public be notified of the Works through appropriate notification in the media and/or at publicly accessible sites (including the site of the works)<br>(c) All legally required permits obtained for construction and/or rehabilitation<br>(d) Contractor formally agrees that all work be carried out in a safe and disciplined manner designed to minimize impacts on neighbouring residents and environment.<br>(e) Workers' PPE comply with international good practice (always hardhats, as needed masks and safety glasses, harnesses and safety boots)<br>(f) Appropriate sign posting of the sites to inform workers of key rules and regulations to follow. |
| **A.** General Rehabilitation and /or Construction Activities | Air Quality | (a) Construction debris kept in controlled area and sprayed with water mist to reduce debris dust<br>(b) During project construction dust be suppressed by ongoing water spraying and/or installing dust screen enclosures at site<br>(c) The surrounding environment (sidewalks, roads) be kept free of debris to minimize dust<br>(d) No open burning of construction / waste material at site<br>(e) No excessive idling of construction vehicles at sites |
| | Noise | (a) Construction noise be limited to restricted times agreed to in the permit<br>(b) During operations, the engine covers of generators, air compressors and other powered mechanical equipment be closed, and equipment placed as far away from residential areas as possible |
| | Water Quality | (a) The site establishes appropriate erosion and sediment control measures such as e.g. hay bales and / or silt fences to prevent sediment from moving off site and causing excessive turbidity in nearby streams and rivers. |
| | Waste management | (a) Waste collection and disposal pathways and sites be identified for all major waste types expected from demolition and construction activities.<br>(b) Construction and demolition waste be separated from general refuse, organic, liquid and chemical wastes by on-site sorting and stored in appropriate containers.<br>(c) Construction waste be collected and disposed properly by licensed collectors<br>(d) Records of waste disposal be maintained as proof for proper management as designed.<br>(e) Whenever feasible the contractor to reuse and recycle appropriate and viable materials (except asbestos) |

| ACTIVITY | PARAMETER | MITIGATION MEASURES CHECKLIST |
|---|---|---|
| **B**. Individual wastewater treatment system | Water Quality | (a) The approach to handling sanitary wastes and wastewater from building sites (installation or reconstruction) must be approved by the local authorities<br>(b) Before being discharged into receiving waters, effluents from individual wastewater systems be treated to meet the minimal quality criteria set out by national guidelines on effluent quality and wastewater treatment<br>(c) Monitoring of new wastewater systems (before/after) will be carried out<br>(d) Construction vehicles and machinery will be washed only in designated areas where runoff will not pollute natural surface water bodies. |
| **C**. Physical Cultural | Cultural Heritage | (a) If the facility is to be constructed within a designated historic structure, very close to such a structure, or located in a designated historic district, notification shall be made and approvals/permits be obtained from local authorities and all construction activities planned and carried out in line with local and national legislation.<br>(b) It shall be ensured that provisions are put in place so that artefacts or other possible "chance finds" encountered in excavation or construction are noted and registered. |

In addition, there are a series of potential risks that are related to or linked with Climate Change. These are, for example, likely to alter or increase the water requirements of downstream communities, as well as the requirements for agriculture, and for other water related sectors of the economy. The relevant sectors are likely to include: Agriculture, Energy, Health, Biodiversity and Ecosystems, as indicated above under the section on Climate Change. Risk management related to Climate Change will need to be carried out in conjunction and collaboration with the new Climate Change Authority, established by Bill of Parliament and signed into law in May 2016.

Similarly, there are long-term risks associated with the onset of Peak Oil, and predicted increases in crude oil prices, resulting in increased costs and changes to sectors of the economy. Current trends in the international crude oil prices, based on daily price data from the year 2000 to the present, indicate a trend towards a doubling of current crude oil prices by the year 2018. Such cost increases may result in changes in the tendency for population increase in the major urban. Such changes would modify the demands for waste water services. Risk management therefore needs to be aware of this potential situation and the possible requirements for changes in the wastewater management schemes.

## 16.0  CONCLUSION OF THE MASTER PLAN

The current sanitation system in Kilifi Town comprising of on-plot sanitation means such as septic tanks and pit latrines and lacking a proper sludge management and disposal facility is a health hazard to the residents and an environmental risk.

As an immediate intervention, construction of Ablution Blocks at designated Public Places and a centralized Sludge Handling Facility is necessary. It is equally important to ensure procurement of Sewage Exhaust Vehicles to provide desluging and transport services. A summary of the Immediate Sanitation Measures and their costs estimates are given **Tables 16.1** and **16.2** below.

**Table 16.1: Details of the Ablution Blocks – Immediate Sanitation Measures**

| Number Proposed | Details of each Ablution Block | | | Total Capital Cost | |
| :---: | :---: | :---: | :---: | :---: | :---: |
| | No. of Toilets | No. of Shower Rooms | Max. Daily users | Ksh. | USD |
| 6 | 6 | 2 | 720 | 93,000,000 | 902,913 |

**Table 16.2: Details of the Sludge Handling Facility – Immediate Sanitation Measures**

| S/No. | Component | Details | Total Capital Cost | |
| :---: | :--- | :--- | :---: | :---: |
| | | | Ksh. | USD |
| 1 | Tanker Discharge Bay | • Bar Screens, Collection Chamber, Hard-stand Washing Bay & Parking Space | 58,299,957 | 566,019 |
| 2 | Sludge Drying Beds | • 8 Beds; each 13 x 10m | | |
| 3 | Twin-Septic Tanks | • 2 Tanks; each 98 m³ capacity | | |
| 4 | Land Requirement | • 0.7 Ha | | |
| 5 | Exhaust Discharge Tanker | • Minimum 1 Nr (Either owned by KIMAWASCO or Private Providers) | - | - |

To provide a sustainable sanitation system, a centralized Wastewater Management Scheme comprising of a gravity sewage conveyance system with limited pumping (11 Nr Pumping Stations) and a Waste Stabilization Ponds system based Wastewater Treatment Plant (ultimate capacity – 12,000 m³/d) at Uhuru Farm has been selected from the developed Alternative Schemes. The implementation of this strategy is to be carried out in 2 phases i.e. Medium Term Plan (2021 -2025) and Long Term Plan (2026 – 2040).

The implementation details of the selected Wastewater Management Scheme in the 2 Phases are given in **Tables 16.3** below and **Table 16.4** on **Page 16-2**.

**Table 16.3: Summary of Implementation Cost: Medium-Term Plan Plan (2021 -2025)**

| S/No. | Component | Details | Cost (Kshs) | Cost (USD) |
| :---: | :--- | :--- | :---: | :---: |
| 1 | Land Acquisition | • 30 Ha | 1,804,236,233 | 17,516,857 |
| 2 | Sewers | • 225 – 600 mm Dia; Total length 32 km | | |
| 3 | Pumping Stations | • 6 Nr | | |
| 4 | Waste Water Treatment Plant | • Waste Stabilization Ponds; Capacity 6,000 m³/d | | |

**Table 16.4: Summary of Implementation Cost: Long-Term Plan Plan (2026 -2040)**

| S/No. | Component | Details | Cost (Kshs) | Cost (USD) |
|---|---|---|---|---|
| 1 | Sewers | • 225 – 375 mm Dia; Total length 45 km | | |
| 2 | Pumping Stations | • 5 Nr | 1,573,234,818 | 15,274,124 |
| 3 | Waste Water Treatment Plant | • Waste Stabilization Ponds; Capacity 6,400 m³/d | | |

Financial analysis of the selected Wastewater Management Scheme presented the following Financial Ratios / Performance Indicators;

- **Benefit - Cost (BC) Ratio;**         1.08 – 1.51

- **Net Present Values (NPV);**         Ksh. 1,326,806,064@ 5% cost of capital

                                            Ksh. 435,216,677 @ 8% cost of capital

- **Financial Internal Rate of Return (FIRR);**    11.30%

On the other hand, economic analysis presented the following Performance Indicators;

- **Net Present Values (NPV);**         Ksh. 554,613,517 @ 10% cost of capital

                                            Ksh. 267,968,361 @ 12% cost of capital

- **Economic Internal Rate of Return (EIRR);**    16%

The results of the economic analysis after including other economic benefits showed that the project would have a positive NPV of Kshs 554,613,517  and EIRR of 16% at 10% cost of capital. These values confirm that the project is economically viable.