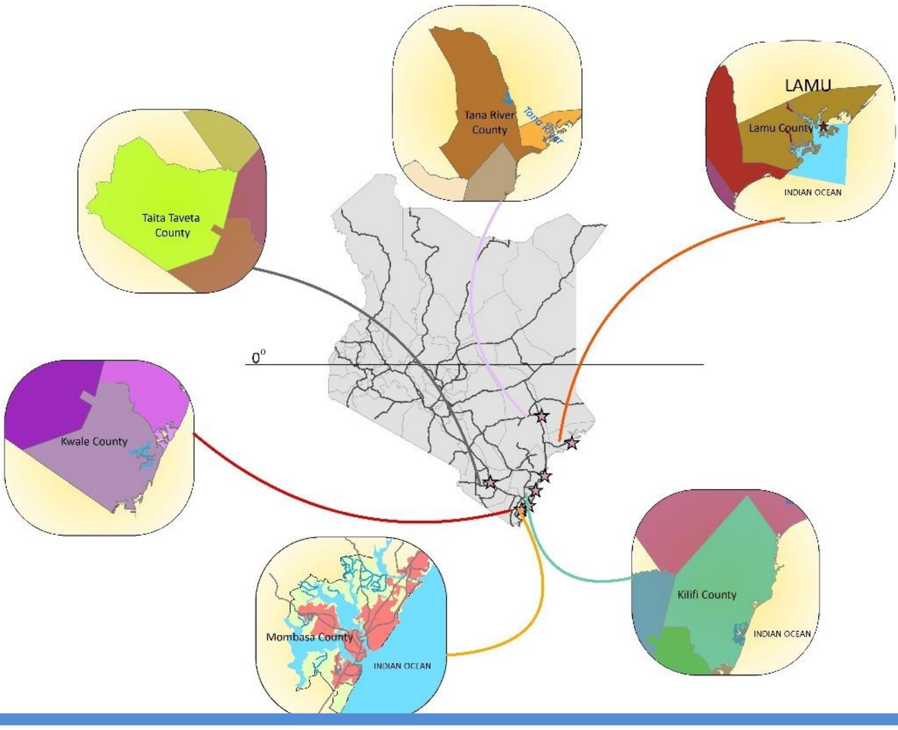
REPUBLIC OF KENYA

COAST WATER SERVICES BOARD

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



Consulting Services for Wastewater 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 LAMU ISLAND

VOLUME 1: MASTER PLAN MAIN REPORT

MIBP
+PARTNERS
CONSULTING ENGINEERS

In Association with:

CES
Consulting Engineers
Salzgitter GmbH

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MARCH 2017

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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

EMPLOYER:

Coast Water Services Board (CWSB)

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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– LAMU

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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
LAWASCO	-	Lamu 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	-	Wastewater Treatment Plant

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 over the next twenty-five (25) years to improve the quality of effluent to rivers, Indian Ocean and groundwater and to safeguard the health of the city's residents."

The key objective of the proposed Master Plan for Lamu Island 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 Lamu Island.

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 Lamu Island.

The components of this Report include the following;

- Present Sanitation Situation in the Study Area & Proposed Immediate Interventions
- Future Sewerage System / Coverage Area Expansion
- Analysis of Sewage Generation and Network Analysis
- Formulation of Alternative Wastewater Management Strategies
- Detailed Evaluation of the Alternative Wastewater Management Strategies including Wastewater Treatment, Social / Environmental Assessment, Economic and Financial Analysis and Multi-Criteria Analysis
- Description of Selected Wastewater Management System Development Strategy
- Investment and Financial Management Plan
- Proposed Implementation / Development Schedule
- Conclusion of the Master Plan

E3 STUDY AREA AND DEMOGRAPHY

Lamu County is formed by the Lamu Archipelago which is a group of small islands (Lamu, Manda, Pate and Kiwayuu) in Kenya's Northern Coast line near Somalia. Lamu Island covers approximately 55 km^2 of Lamu County coverage (6,475km^2). The study area for Lamu Island Wastewater Master Plan is approximately 10% of the total area covered by Lamu Island.

The sub-locations forming Lamu Island and total coverage areas as well as the study area is given in **Table E1** below;

Table E1: Sub-locations and Study Area

Sub-locations	Total Area (km²)	Coverage in the Study Area (km²)
Shela	17.3	2.3
Mkomani	4.9	2.7
Langoni	3.0	2.1
Total	**25.2**	**7.1**

Figure E1 on **E-2** shows the coverage of the Study Area of Wastewater Master Plan for Lamu Island.

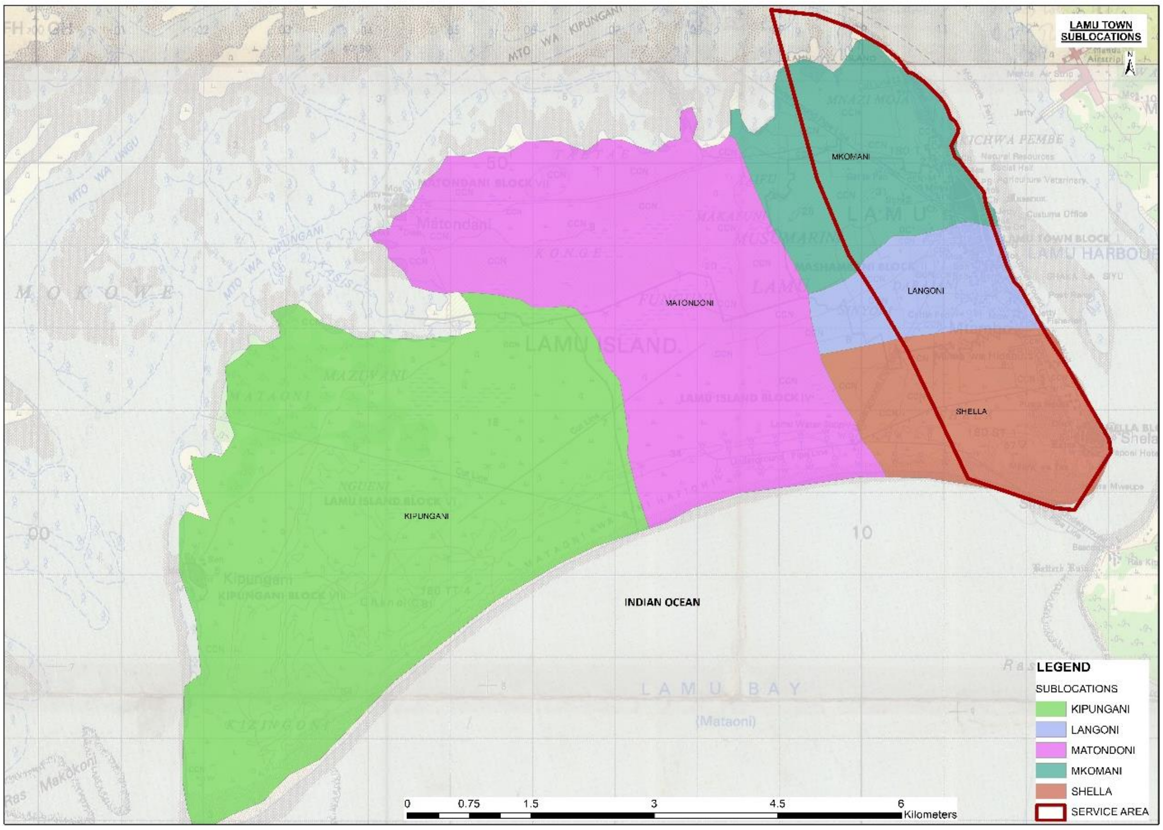


Figure E1: Study Area of Wastewater Master Plan for Lamu Island

The analysis of previous demographic data obtained from Central Bureau of Statistics (CBS) indicates that the average annual growth rate for the Study Area within the Period 1999 to 2009 is **3.01%.** This is expected to experience gradual increase owing to the Town's potential and planned infrastructural and industrial developments.

The future population of the study Area has been projected based on a medium growth rate scenario with annual population growth rate increasing from **3.8%** in 2015 to **4.3%** in **2040**.

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

Table E2: Summary of Population Projection within the Study Area

Sub-locations	2009	2015	2020	2025	2040
	Growth Rate (%)				
	-	3.8%	4.0%	4.2%	4.3%
Shela	2,579	3,226	3,924	4,821	9,065
Mkomani	3,783	4,732	5,757	7,072	13,298
Langoni	6,849	8,566	10,422	12,802	24,074
Total	**13,210**	**16,523**	**20,103**	**24,695**	**46,438**

E4 WATER DEMAND FORECAST

Water demand forecast for Lamu Island 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 on **Page E-3** shows the water demand projection for Lamu Island up to the Ultimate Design Horizon (year 2040).

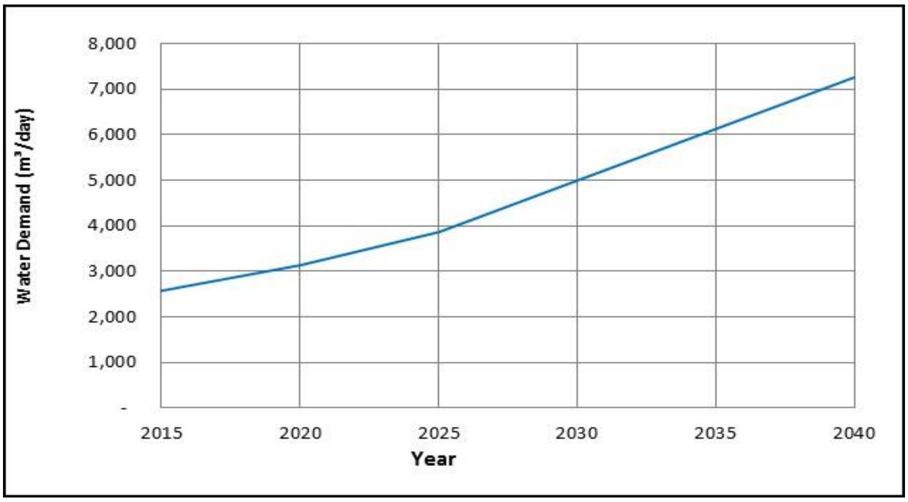


Figure E2: Water Demand Projection

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 Lamu Island in the year 2040, is approximately **6,200 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 necessitated by 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 **Tables E3** and **E4** below, have been adopted for the formulation of realistic wastewater generation projection for Lamu Island.

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 on **Page E-4** shows the comparative projected wastewater flows for Lamu Island 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);

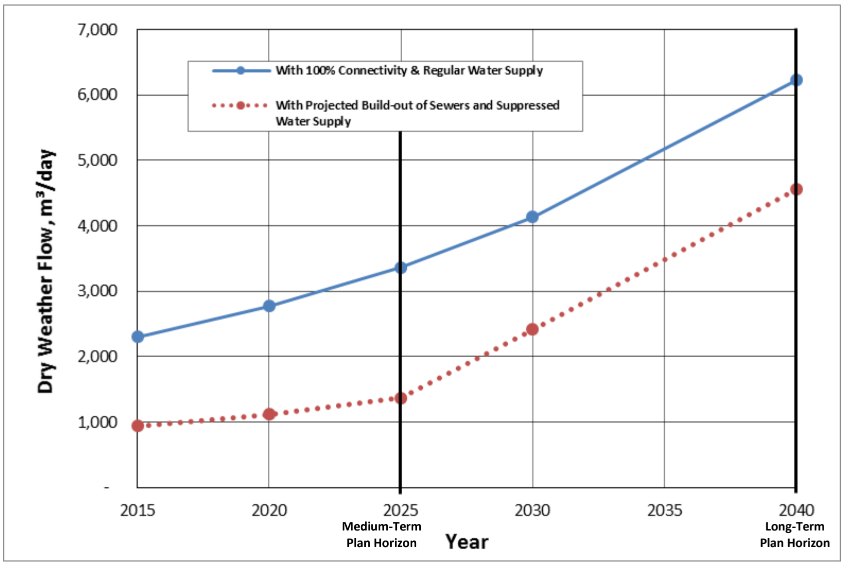


Figure E3: Comparative Projected Wastewater Flows up to Year 2040

From **Figure E3** above, the projected wastewater generation, based on the realistic conditions of suppressed water supply and gradual implementation of sewer connections, in the Years 2025 and 2040 is 1,400 m^3/day and 4,600 m^3/day respectively.

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

E6 WASTEWATER MANAGEMENT STRATEGIES

The Final Wastewater Master Plan for Lamu Island 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 treated effluents. However, this 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 to be implemented between year 2017 and 2019. These measures include construction of 4 Nr Ablution Blocks at selected public places and a centralized Sludge Handling Facility.

As a long-term strategy, a Centralized Wastewater Management Scheme consisting of Trunk and Secondary Sewers and a Wastewater Treatment Plant comprising of Waste Stabilization Ponds (ultimate capacity 4,600 m^3/d) is proposed. The proposed Wastewater Treatment Plant is to be sited at undeveloped land at Taifu area. There is no alternative scheme since the topography of service area for Lamu Island results to a single low point at which the Wastewater Treatment Plant has been proposed.

A summary of the proposed Wastewater Management scheme for Lamu Island is given in **Table E5** below.

Table E5: Details of the Proposed Wastewater Management Scheme

Conveyance System		Wastewater Treatment Plant			
Secondary and Trunk Sewers (km)	No. of Pumping Stations	Location	Design Capacity (m^3/day)	Treatment Technology	Land Required (Ha)
21	10	Taifu area	4,600	Waste Stabilization Ponds	15

The location of the Wastewater Treatment Plant (WWTP) in the proposed scheme is shown in **Figure E4** below;

Figure E4: Location of the Proposed Wastewater Treatment Plant

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 Lamu Island.

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 and Maintenance	Net Present Value	Environmental Impacts	Land Requirement	Institutional Strength	Weighted Total	Rank
Waste Stabilization Ponds	0.690	0.600	0.532	0.156	0.656	0.584	1
Composite Biofilters	0.156	0.252	0.303	0.269	0.208	0.253	2
Composite Oxidation Ditches	0.153	0.149	0.165	0.575	0.136	0.162	3

Lamu Island has a definite topography and only one site has been identified as suitable for the development of Wastewater Treatment Plant. Thus, it has only a Centralized Wastewater Management Scheme consisting of a Gravity and Pumping based Sewerage System with a Waste Stabilization Ponds System at the undeveloped site at Taifu area. This Scheme is recommended for Lamu Island Sanitation Strategy.

E8 PROJECT COSTS

The Capital Cost of the Proposed Wastewater Management Scheme for Lamu Island 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 E7** below;

Table E7: Capital Costs for the Proposed Scheme

S/No.	Component	Costs (Kshs)	Costs (USD) [1]
1	**Land Acquisition**	**75,000,000**	**728,155**
2	**Civil Works**	**850,817,517**	**8,260,364**
2.1	Wastewater Treatment Plant	459,948,335	**4,465,518**
2.2	Pumping Stations	58,000,009	**563,107**
2.3	Sewers	332,869,174	**3,231,740**
3	**Electro-Mechanical Works**	**62,874,480**	**610,432**
3.1	Wastewater Treatment Plant	24,207,807	**235,027**
3.2	Pumping Stations	38,666,673	**375,405**
	Total Capital Cost	**988,691,997**	**9,598,951**

A summary of the Phased Investment cost for Lamu Island Wastewater Management System is given in **Tables E8** and **E9** below;

Table E8: Costs for Medium-Term Plan (Year 2020 – 2025)

S/No.	Component	Cost (Kshs)	Costs (USD) [1]
1	Land Acquisition	75,000,000	728,155
2	Sewerage System	265,564,306	2,578,294
3	Wastewater Treatment Plant	269,761,663	2,619,045
	Total	**610,325,969**	**5,925,494**

Table E9: Costs for Long-Term Plan (Year 2026 – 2040)

S/No.	Component	Cost (Kshs)	Costs (USD) [1]
1	Sewerage System	163,971,549	1,591,957
2	Wastewater Treatment Plant	214,394,478	2,081,500
	Total	**378,366,027**	**3,673,457**

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

a) Electricity Costs at the Pumping Stations is assumed to increase annually at the population growth rate due to increased sewer 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 E10** below;

Table E10: Annual Operations & Maintenance Costs (Year 1)

S/No.	Component	Costs (Kshs)	Costs (USD) [1]
1	Maintenance Costs	11,651,899	113,125
2	Electricity Costs	717,428	6,965
3	Staff Costs	5,064,000	49,165
	Total O&M Cost	**17,433,327**	**169,256**

[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 E11** below;

Table E11: Schedule of Annual Project Expenditures

Year	Project Cost, Ksh	O&M, Ksh	Depreciation, Ksh	Total Cost, Ksh
2021	152,581,492			152,581,492
2022	152,581,492			152,581,492
2023	152,581,492	17,433,327.35	17,751,133.10	187,765,953
2024	152,581,492	17,462,024.48	23,668,177.47	193,711,694
2025	-	17,494,856.87	23,668,177.47	41,163,034
2026	37,836,603	17,527,573.09	25,008,489.39	80,372,665
2027	37,836,603	17,561,663.39	26,475,776.51	81,874,043
2028	37,836,603	17,597,185.49	27,943,063.62	83,376,852
2029	-	17,634,199.52	27,943,063.62	45,577,263
2030	56,754,904	17,672,768.13	30,143,994.29	104,571,667
2031	75,673,206	17,712,956.63	30,275,225.77	123,661,388
2032	94,591,507	17,754,833.04	31,140,100.81	143,486,441
2033	37,836,603	17,798,468.27	29,804,045.17	85,439,116
2034	-	17,843,936.17	27,000,702.43	44,844,639
2035	-	17,891,313.72	27,000,702.43	44,892,016
2036	-	17,940,681.13	26,432,514.89	44,373,196
2037	-	17,992,121.98	25,737,352.17	43,729,474
2038	-	18,045,723.34	25,042,189.44	43,087,913
2039	-	18,101,575.95	25,042,189.44	43,143,765
2040	-	18,159,774.38	23,999,445.35	42,159,220
2041	-	18,159,774.38	23,999,445.35	42,159,220
2042	-	18,159,774.38	23,999,445.35	42,159,220
2043	-	18,159,774.38	23,999,445.35	42,159,220
2044	-	18,159,774.38	23,999,445.35	42,159,220
2045		18,159,774.38	20,176,050.37	38,335,825
2046		18,159,774.38	20,176,050.37	38,335,825

Assuming adoption of the proposed tariffs and attainment of the projected sewer connections, the projected financial statement has been determined and summarized in **Table E12** below.

Table E12: Projected Financial Statement of the Project

Project Income and expenditure Financial statement (Ksh)							
Year	Total Project Revenue	Billings Not Recovered	Net Project Revenue	Operations & Maintenance	Annual Depreciation	Total Expenditure	Net Revenue
2023	42,038,852	4,203,885	37,834,967	17,433,327	17,751,133	35,184,473	2,650,493
2024	42,038,852	4,203,885	37,834,967	17,462,024	23,668,177	41,130,215	-3,295,249
2025	51,640,381	5,164,038	46,476,343	17,494,857	23,668,177	41,163,048	5,313,295
2026	74,776,648	7,477,665	67,298,983	17,527,573	25,008,489	42,536,076	24,762,907
2027	74,776,648	7,477,665	67,298,983	17,561,663	26,475,777	44,037,454	23,261,529
2028	74,776,648	7,477,665	67,298,983	17,597,185	27,943,064	45,540,264	21,758,720
2029	74,776,648	7,477,665	67,298,983	17,634,200	27,943,064	45,577,278	21,721,705
2030	131,861,714	13,186,171	118,675,542	17,672,768	30,143,994	47,816,778	70,858,764
2031	131,861,714	13,186,171	118,675,542	17,712,957	30,275,226	47,988,198	70,687,344
2032	131,861,714	13,186,171	118,675,542	17,754,833	31,140,101	48,894,950	69,780,592
2033	131,861,714	13,186,171	118,675,542	17,798,468	29,804,045	47,602,530	71,073,012
2034	131,861,714	13,186,171	118,675,542	17,843,936	27,000,702	44,844,655	73,830,887
2035	131,861,714	13,186,171	118,675,542	17,891,314	27,000,702	44,892,033	73,783,509
2036	131,861,714	13,186,171	118,675,542	17,940,681	26,432,515	44,373,214	74,302,328
2037	131,861,714	13,186,171	118,675,542	17,992,122	25,737,352	43,729,492	74,946,050
2038	131,861,714	13,186,171	118,675,542	18,045,723	25,042,189	43,087,931	75,587,611
2039	131,861,714	13,186,171	118,675,542	18,101,576	25,042,189	43,143,784	75,531,758
2040	248,647,972	24,864,797	223,783,175	18,159,774	23,999,445	42,159,239	181,623,935
2041	248,647,972	24,864,797	223,783,175	18,159,774	22,609,120	40,768,914	183,014,260
2042	248,647,972	24,864,797	223,783,175	18,159,774	20,871,213	39,031,008	184,752,167
2043	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,846	185,447,329
2044	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,846	185,447,328
2045	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,847	185,447,328
2046	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,847	185,447,327

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 **1.57** to **1.08**. The financial analysis confirms that the project has positive NPVs of **Ksh 463,012,165** at 5% cost of capital and **Ksh 151,115,540** at 8% cost of capital and Financial Internal Rates of Return (FIRR) of **11.24** %.

Sensitivity analyses also indicate that the viability of the Project is susceptible to shocks due to variations in Project Costs and 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 265,939,817** and **EIRR of 19%** at 10% cost of capital.

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

E10 CONCLUSION OF THE MASTER PLAN

The current sanitation system in Lamu Island which lacks a proper sludge management and disposal systems but comprises of on-plot sanitation measures such as septic tanks and pit latrines is a health hazard to the residents and an environmental risk.

As an immediate intervention, construction of 4Nr Ablution Blocks at selected Public Places and a centralized Sludge Handling Facility is necessary. It is equally important to ensure procurement of Exhaust Vehicles to provide desludging and transport services. A summary of the Immediate Sanitation Measures and their cost estimates are given on **Tables E13** and **E14** below.

Table E13: 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
4	6	2	720	62,000,026	601,942

Table E14: 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	35,499,980	344,660
2	Sludge Drying Beds	• 4 Beds; each 13 x 10m		
3	Twin-Septic Tanks	• 2 Tanks; each 98 m³ capacity		
4	Land Requirement	• 0.5 Ha		
5	Exhaust Discharge Tanker	• Minimum 1 Nr (Either owned by LAWASCO or Private Providers)	-	-

To provide a sustainable sanitation system, a centralized Wastewater Management Scheme has been selected for Lamu Island comprising of a sewage conveyance system including 10 Nr Pumping Stations and a Waste Stabilization Ponds system (ultimate capacity – 4,600 m³/d) at undeveloped land in Taifu area.

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 including the associated costs are given in **Table E15** and **E16** below.

Table E15: Summary of Implementation Cost: Medium-Term Plan (2021-2025)

S/No.	Component	Details	Cost (Kshs)	Cost (USD)
1	Land Acquisition	• 15 Ha	610,325,969	5,925,494
2	Sewers	• 225 – 450 mm Dia; Total length 13 km		
3	Pumping Main	• 100 mm Dia; Approx. Total Length 220 m		
4	Wastewater Treatment Plant	• Waste Stabilization Ponds; Capacity 2,300 m³/d		

Table E16: Summary of Implementation Cost: Long-Term Plan Plan (2026 -2040)

S/No.	Component	Details	Cost (Kshs)	Cost (USD)
1	Sewers	• 225 mm Dia; Total length 7 km	378,366,027	3,673,457
2	Pumping Main	• 100 mm Dia; Approx. Total Length 1,085 m		
3	Wastewater Treatment Plant	• Waste Stabilization Ponds; Capacity 2,300 m³/d		

Financial analysis of the selected Wastewater Management Scheme presented the following Financial Ratios / Performance Indicators;

- **Benefit – Cost (BC) Ratio;** 1.57 – 1.08
- **Net Present Values (NPV);** Ksh. 463,102,165 @ 5% cost of capital
  Ksh. 151,115,540 @ 8% cost of capital
- **Financial Internal Rate of Return (FIRR);** 11.24 %

On the other hand, economic analysis presented the following Performance Indicators;

- **Net Present Values (NPV);** Ksh. 265,939,817 @ 10% cost of capital
- **Economic Internal Rate of Return (EIRR);** 19 %

Sensitivity analysis of the financial parameters indicates that the scheme's viability is susceptible to shocks due to Project Cost, Total Net Income and Operations and Maintenance Costs.

Thus, it can be concluded that the selected scheme is both financially and economically viable.

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 Wastewater 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 and Ukunda / Diani.
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.**

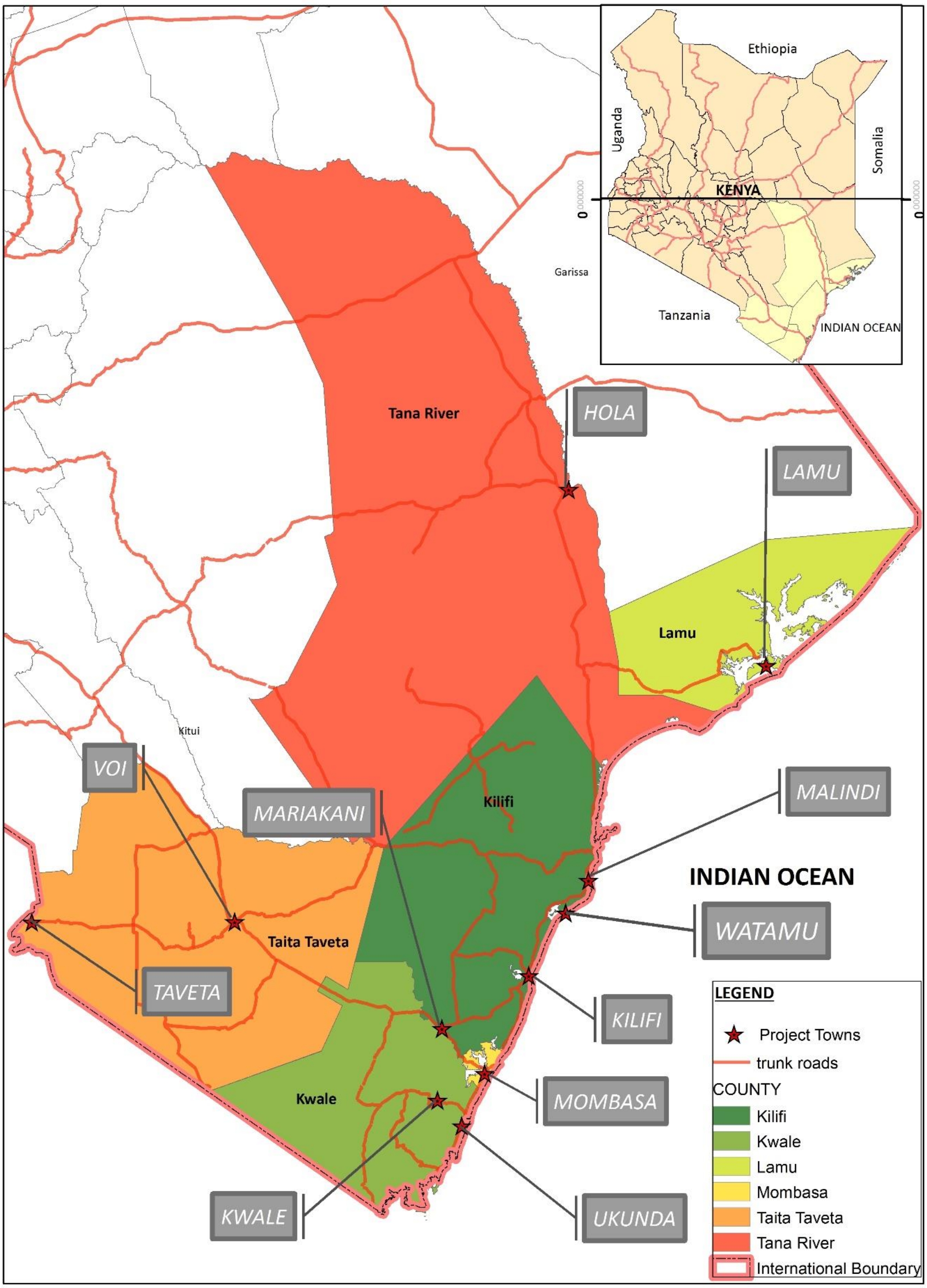


Figure 1.1: Location Plan for the Project Towns

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 over the next twenty-five (25) years i.e. up to Year 2040, to improve the quality of effluent to rivers, Indian Ocean and groundwater and to safeguard the health of the residents of the Study Areas."

The key objective of the proposed Master Plan for Lamu Island 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 Lamu.

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 – Wastewater Flow Predictions & Formulation of Sewerage Development Strategies,
- D7 – Preliminary Design Report for Medium Term Works including Phased Investment Schedule for Sewers and Wastewater Treatment Plants,
- D8 - Preliminary Environmental and Social Impact Assessment (ESIA) & Preliminary Resettlement Action Plan (RAP) for the Preferred Development Strategy

The Final 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 Lamu Island.

- D9 – Final Master Plan Report

1.3 Objectives of this Report

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

- Present Sanitation Situation in the Study Area and Proposed Immediate Interventions
- Future Sewerage System / Coverage Area Expansion
- Analysis of Sewage Generation and Network Analysis
- Formulation of Alternative Wastewater Management Strategies
- Detailed Evaluation of the Alternative Wastewater Management Strategies including Wastewater Treatment, Social / Environmental Assessment, Economic and Financial Analysis and Multi-Criteria Analysis
- Description of Selected Wastewater Management System Development Strategy
- Investment and Financial Management Plan
- Proposed Implementation / Development Schedule
- Conclusion of the Master Plan

2.0 PROJECT AREA DESCRIPTION

2.1 Location and Administration

Lamu County is formed by the Lamu Archipelago which is a group of small islands (Lamu, Manda, Pate and Kiwayuu) in Kenya's Northern Coast line near Somalia. Lamu Island is approximately 350 km from Mombasa and is linked by Sea channel to the Mombasa North Mainland at Mokowe. It covers approximately 55 km^2 of Lamu County coverage (6,475 km^2).

Lamu Island is situated at approximately Longitude 40° 47' and 40° 55' East and Latitude 2° 14' and 2° 20' South of the Equator. It is headquarters of Lamu County, formerly Lamu District. It is located within Lamu West Sub-County and borders the Indian Ocean to the east, Tana River County to the South West, Garissa County to the North and the Republic of Somalia to the North East.

Lamu Island is a host to one of the oldest and best preserved Swahili settlements. It is characterized by simple, coral stone structures enriched by inner courtyards, verandas and beautiful, elaborately curved mangrove wood doors. Lamu is a protected UNESCO National Heritage site.

Water supply and sanitation systems in Lamu Island is managed by Lamu Water and Sewerage Company Ltd. (LAWASCO).

2.2 Study Area

The study area for the Wastewater Master Plan is approximately 10% of the total area covered by Lamu Island. The Study Area has been demarcated in consideration of the location of core urban areas within Lamu Island, projected land use plans for years 2025 and 2040 and the nature of development and population densities.

The sub-locations forming Lamu Island and total coverage areas as well as the study area is given in **Table 2.1** below;

Table 2.1: Sub-locations and Study Area

Sub-locations	Total Area (km^2)	Coverage in the Study Area (km^2)
Shella	17.3	2.3
Mkomani	4.9	2.7
Langoni	3.0	2.1
Total	**25.2**	**7.1**

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

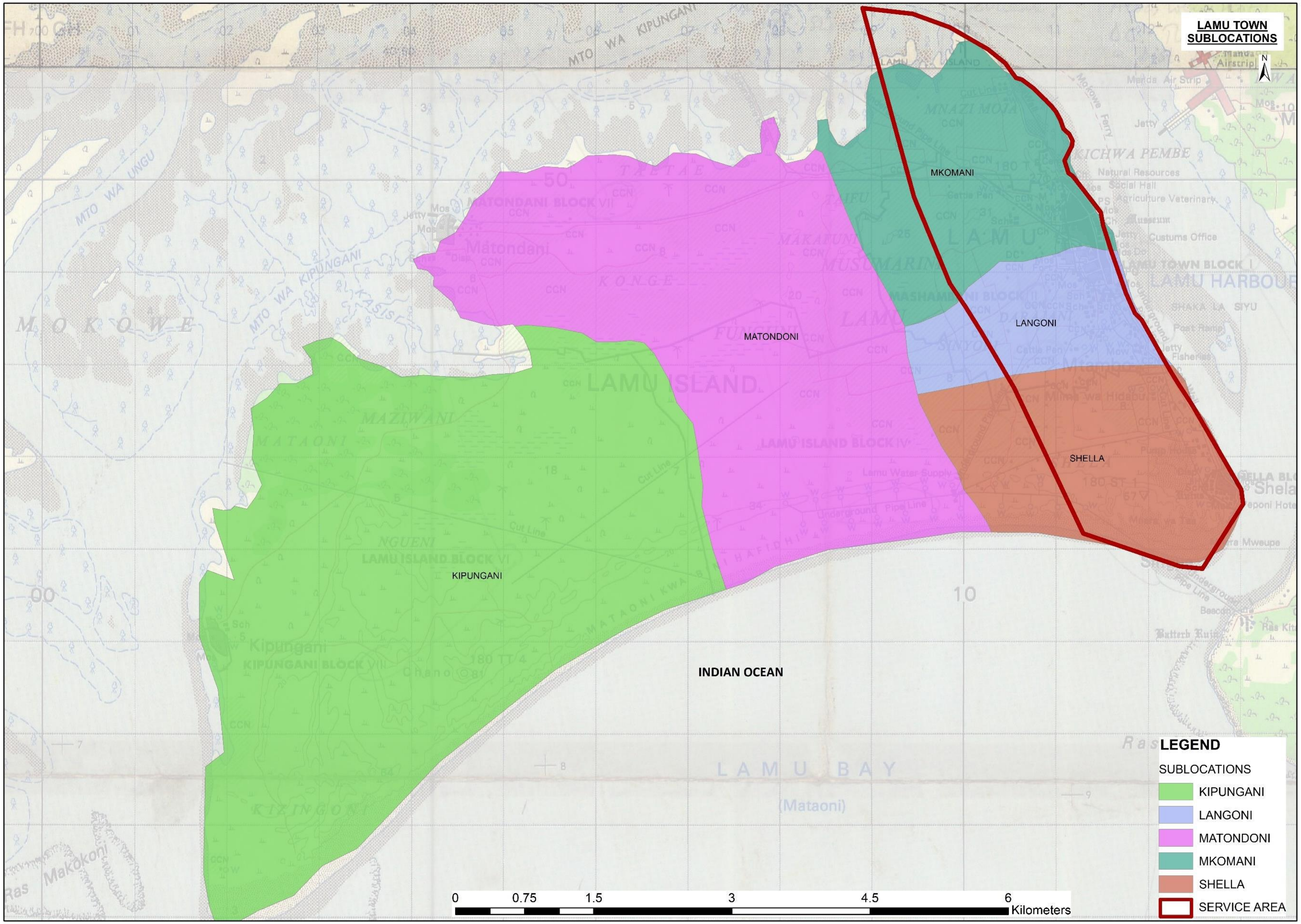


Figure 2.1: Study Area of Wastewater Masterplan for Lamu

2.3 Climate

Lamu County is marginally semi-arid with two rainy seasons in a year. The long rains fall between April and June and the short rains between October and November. The average annual rainfall varies between 550 mm and 850 mm due to effects of the monsoon winds and the topography with marked decrease in intensity towards the hinterland.

Lamu County is generally hot and humid all the year round with temperature ranging between 23°C and 32°C. The hottest months are December to April and the lowest temperature is experienced during the long rainy seasons. Average relative humidity along the coastal belt is 65% but decreases towards the hinterland.

2.4 Topography, Geology and Soils

Lamu County is generally flat and lies between 0 to 50 meters above sea level. Part of the Islands becomes flooded during high tides. The many beaches are characterized by coral cliff, sandy soil and is an unstable new dune formation.

The main topographical features include Coastal Plains, Island Plains and Sand Dunes. The best agricultural land is sound on the Coastal and Island Plains. Sand dunes are found on the southern parts of the County. The dunes rise to a height of about 50 meters above sea level and are a source of fresh water during drought. There are a few seasonal streams flowing towards the South East, however, none of the streams reach the Indian Ocean.

2.5 Economic Activities

Agriculture and livestock rearing is the main economic activity in the hinterland. The rich agricultural and livestock zone in the hinterland is comprised of settlement schemes with land parcels ranging between 10 to 15 acres. Farming is the main economic activity and there is a high population density. They grow major food crops during the long rains and drought-resistant crops during the short rains. Agriculture is not technologically developed.

The marine zones are predominant on the Islands where fishing and tourism are the main economic activities. Communities here live in villages along the beaches where fresh water is available.

Formal sector activities in Commerce, Trade and Services are mainly concentrated in Lamu Old Town. The commercial and trade sector largely depends on tourism.

2.6 Existing Water Supply and Sanitation Systems

2.6.1 Water Supply

Lamu is supplied with fresh water from 30 Nr. Shallow wells of approximate depth, 20 m, situated within Lamu Island. Abstracted water is chlorinated at Shella Pump House before conveyance to various storage reservoirs within the Island in Lamu. The conveyance system entails Water Pumping Mains, Storage Reservoirs and Distribution Mains.

The existing water supply system is summarised in **Table 2.2** on **Page 2-4**.

The water supply for Lamu is inadequate to serve the current demands as well as the future needs of the growing population. Therefore, development of additional water resources and extension of the distribution network is required.

Table 2.2: Summary of Existing Water Supply System for Lamu Island

Water sources	30Nr Shallow wells approximately 20m deep
Water Pumping	Submersible pumps at wells. High lift pumps at Shella pump house (submersible pumps)
Water Treatment	Chlorination at Shella pump house
Water Mains	Pipeline rising mains from wells to sump tanks: • 5km DN 100 AC • 5km DN 100 GI, Class B Pipeline rising mains from sump tanks to storage tanks: • 6km DN 150 AC • 6km DN 150 uPVC, Class D
Water Storage	1 Nr. 450m^3 at LAWASCO office site 2 Nr. 50m^3 at Shella Pump Station site
Water Distribution	0.3km of DN 150 AC 0.7km of DN 100 AC 0.3km of DN 75 AC 2.0km of DN 75 uPVC, Class C 10.0 km of DN 25 to 50 uPVC

2.6.2 Sanitation System

Presently, Lamu Island 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 Sludge Drying Beds or Waste Stabilization Ponds for the discharge of septage by the exhaust vacuum tankers. Thus, septage from septic tanks is discharged directly to the environment such as unrestricted public utility sites.

The use of on-plot sanitation systems, although unsustainable, is manageable in Lamu Island, due to the suppressed water supply situation. If the water supply system is improved through development of additional water resources and expansion of distribution network as per the various Development Plans, the use of on-plot sanitation systems will not suffice in Lamu Island and health and environmental hazards are bound to occur.

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

2.7 Immediate Measures for the Improvement of Sanitation Systems

The Final Wastewater Master Plan for Lamu Island 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, this 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 to be implemented between year 2017 and 2019. These measures include construction of Ablution Blocks in selected Public Places and a Sludge Handling Facility as described in the following sub-sections.

2.7.1 Ablution Blocks

Ablution Blocks are essential in Lamu Island 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 public. Their locations in Lamu Island will be selected in consultation with the CWSB and the Lamu County Government

Considering the population densities and the number of public utilities, a total of four (4) Ablution Blocks is proposed for construction in Lamu Island. 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.

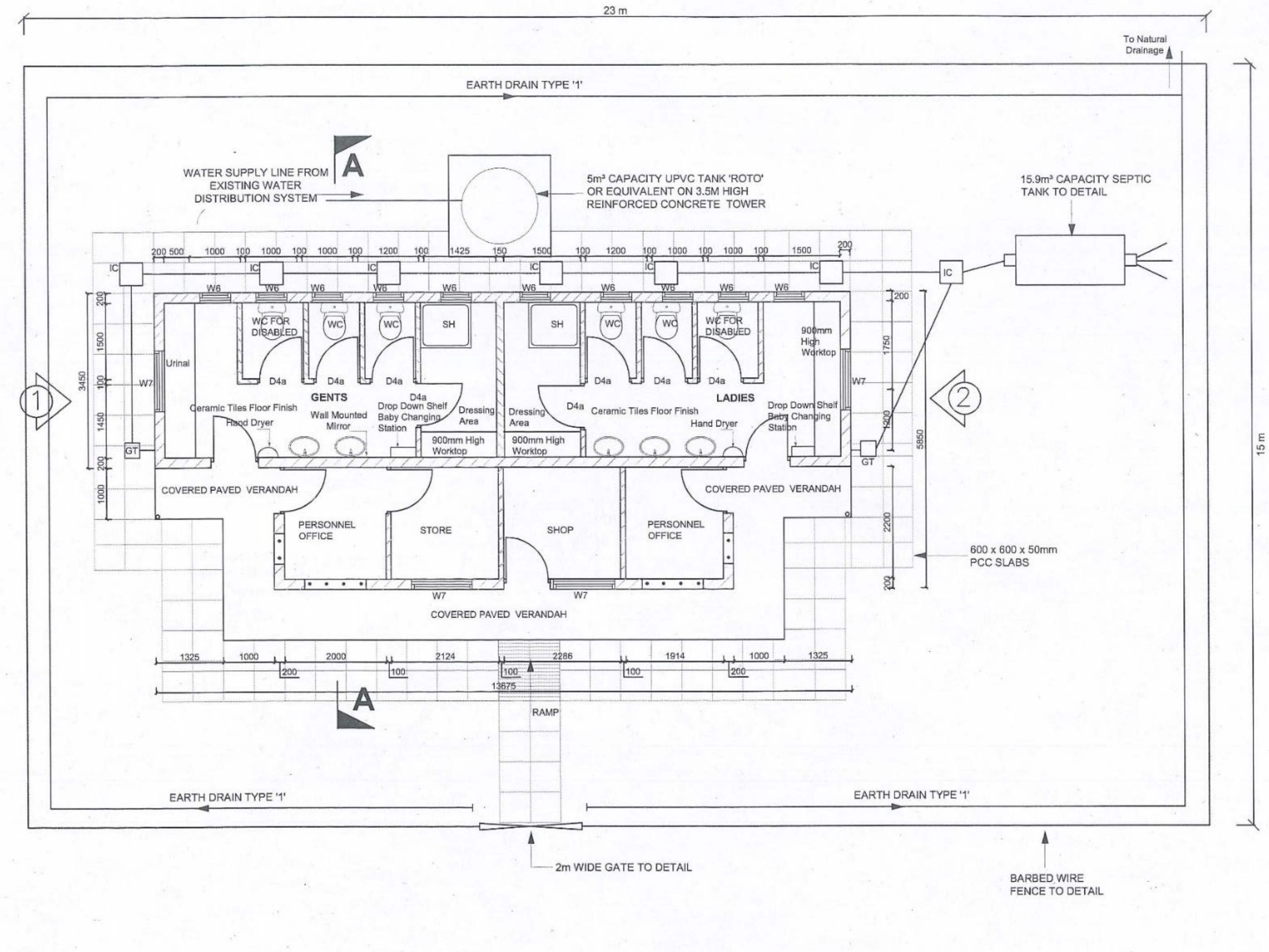
Each of the shower units is fitted with coat hangers behind the doors for convenience. To enhance natural lighting within the facility, transparent polycarbonate roofing material have been incorporated in the design. Proper ventilation is ensured by the louvered windows and gap between the ring beam 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 3.5 m 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, controlled access through 4 m wide metallic gate and boundary chain link fence where applicable.

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 shop for essential commodities and a storage room 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.**



ABLUTION BLOCK
TYPICAL SITE LAYOUT PLAN IN AREAS WITH LIMITED LAND
(AREA REQUIRED 350m²)

Figure 2.2: Typical Site Layout Plan for an Ablution Block

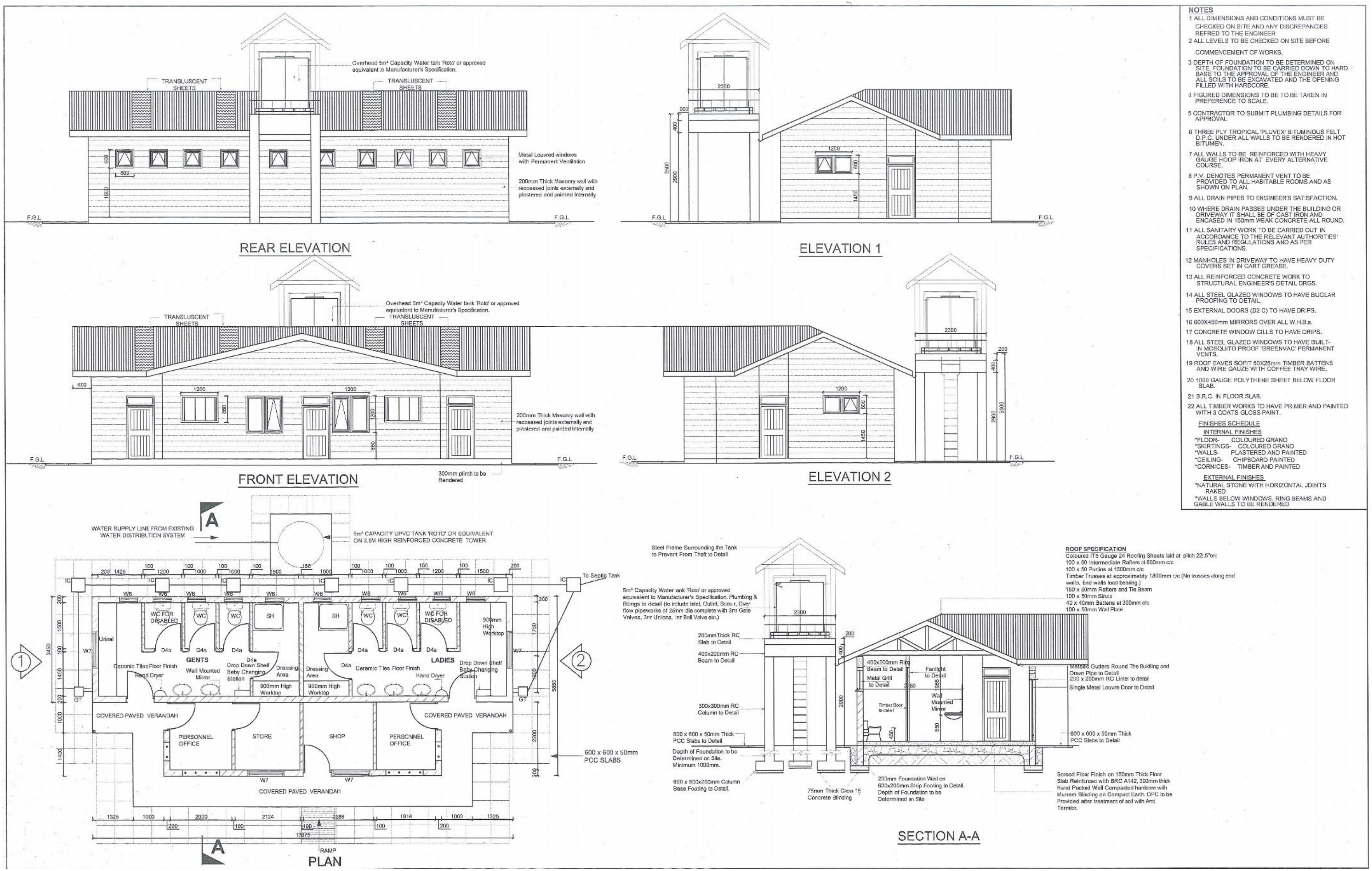


Figure 2.3: Typical Plan, Views and Sections of an Ablution Block

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 an economical distance to the service area but outside the residential developments and environmentally sensitive areas. Thus, the location of the Wastewater Treatment Plant proposed at Taifu area in the Wastewater Master Plan, should be given priority in the site selection for the Sludge Handling Facility. It is preferred that Sludge Handling Facilities site be located within 10km radius to the core urban centre and where land is available and buffer zone for odour and other nuisance control provided.

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 Operators 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 a large footprint than the Septic Tanks and thus not suitable for urban areas like Lamu Island 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 **Figures 2.4** on **Page 2-9**

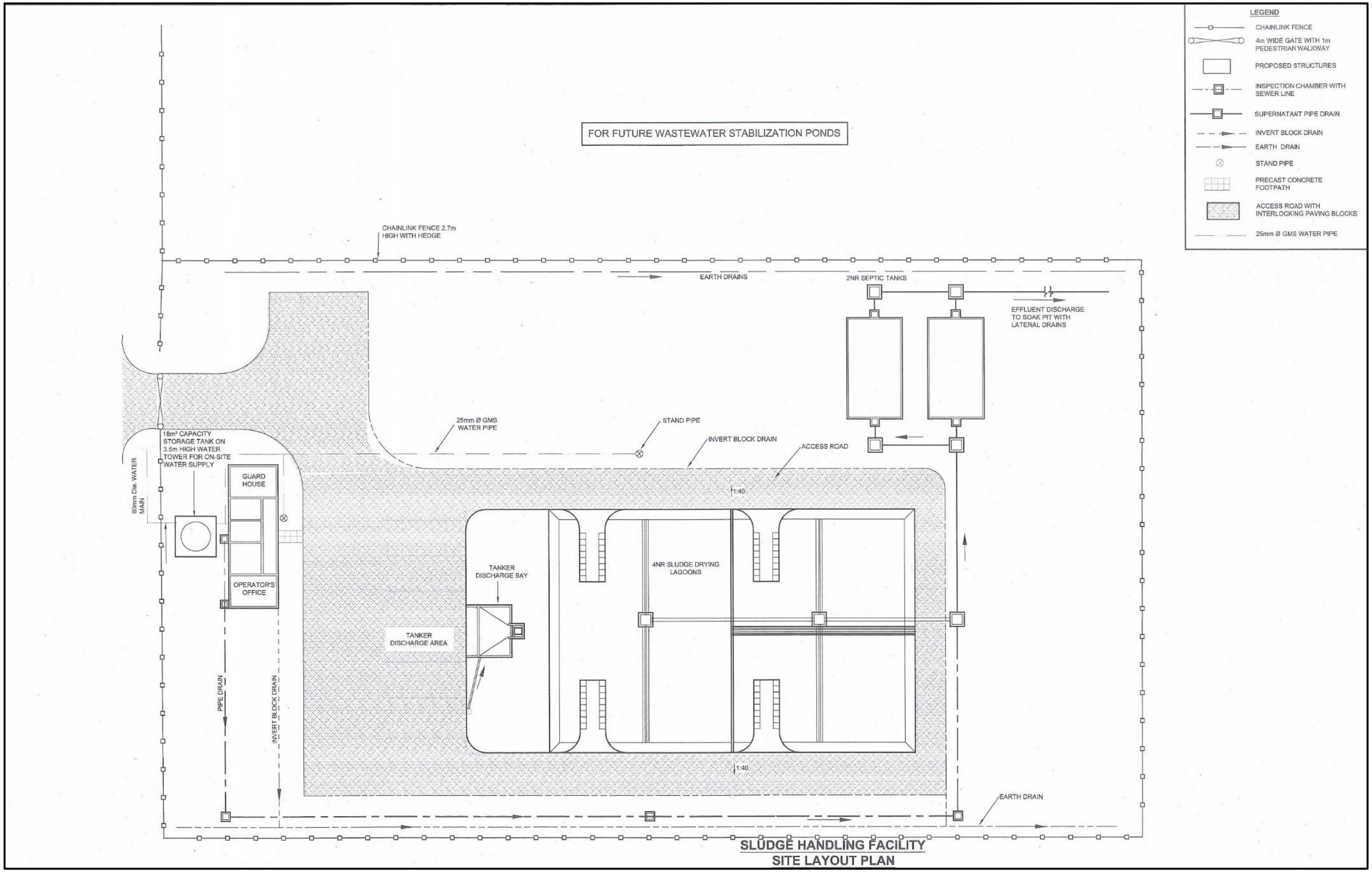


Figure 2.4: Schematic Layout Plan of the proposed Sludge Handling Facility

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 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 provided with precast concrete cover slabs and handrails 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 components:
- 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 with aid of 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 landfills, 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.

Septic Tanks achieve polishing of septage filtrate by the 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. Guard House / Operators Office and Wash-room
iv. Onsite Water Supply and Site Drainage System

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 Lamu Island 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/capital/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 Lamu Island are intended to serve up to the Year 2020, the Facility has been designed to serve 20% of the projected current population i.e. **5,000 persons**. This is because embracement of Sludge Handling Facility is expected to be gradual and for full usage to be experienced, rigorous Public Health Campaigns are necessary.

Details of the various components of the proposed Sludge Handling Facility in Lamu Island 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 • Hard-stand Washing Bay & Parking
2.	Sludge Drying Lagoons / Beds	• 4 No. Beds; each 13 x 10 m • Sludge drying period: 3 months • Treatment zone media = 500 mm thick
3.	Septic Tanks	• 2Nr Twin-Tank; each 9.6 x 5.4 x 1.9 m (L x W x H) & capacity 98 m^3 • 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 Lamu Island**.**

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, Taifu site 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 Lamu Island 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	4	62,000,026	601,942
2.	Sludge Handling Facility	1	35,499,980	344,660

3.0 DEMOGRAPHY, LAND USE AND URBAN DEVELOPMENT

3.1 Demography and Population Dynamics for Lamu Island

Demographic data from Central Bureau of Statistics (CBS), for the inter-census periods 1979 to 1989, 1989 to 1999, and 1999 – 2009 have been analysed to establish trends in terms of population size, and inter-census growth rates, to develop future population projection patterns in Lamu Island.

3.1.1 Previous Population Trend

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

A summary of previous intercensal population data for the areas of interest within Lamu West Sub-county is given in **Table 3.1** below.

Table 3.1: Intercensal Population data (1979 – 2009) for Lamu West Sub-County.

Sub-locations	1979			1989			1999			2009		
	Pop.	Area (km²)	Pop. Density (psn/km²)	Pop.	Area (km²)	Pop. Density (psn/km²)	Pop.	Area (km²)	Pop. Density (psn/km²)	Pop.	Area (km²)	Pop. Density (psn/km²)
Shella	976	-	-	1,760	110	16.00	1,354	15.0	90.27	2,182	17.3	126.13
Mkomani	30	247.0	0.12	4,104	42	97.71	5,724	7.1	806.20	7,040	4.9	1,436.73
Langoni	-	-	-	-	-	-	7,235	5.1	1,418.63	9,793	3.0	3,264.33
Total	**1,006**	**247**	**0.12**	**5,864**	**152**	**114**	**14,313**	**27**	**2,315**	**19,015**	**25**	**4,827**

Population data is dependent on the coverage considered; for the same sub-location and time, a larger area results to a higher population. The use of population figures to establish intercensal population growth rate in a sub-location with varying coverage areas between intercensal period is therefore inaccurate due to the variability of coverage area. It is then 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 Lamu Island.

The previous intercensal annual population growth rates based on the population densities for the sub-locations covered by area of interest for Lamu Island are given in **Table 3.2** below.

Table 3.2: Previous Intercensal Annual Population Growth Rates

Sub-locations	Annual Growth Rates		
	1979-1989	1989-1999	1999-2009
Shella	0.0%	18.9%	3.4%
Mkomani	95.2%	23.5%	5.9%
Langoni	0.0%	0.0%	8.7%
Total	**19.3%**	**9.3%**	**2.9%**

From **Table 3.2** above, the annual population growth rate for Lamu in the last intercensal period (1999 to 2009) is **2.9%.** This is below the 4.2% projected for the growth in Urban Centres under Millennium Development Goals (MDG's) by 2015.

The above population dynamic refers to the resident category. The non-resident category comprising of tourists / visitors has been 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 Lamu Island in the Integrated Development Plan for Lamu County and the potential of Lamu Island for further growth. These factors will result to future immigration and urbanization.

As at the last census (2009), the population within Lamu Island was **13,210**. To forecast the future population of the study area up to the design horizon (year 2040), the following factors have been considered:

- Previous Demographic Trends in Lamu Island and Lamu 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 assessed for 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 population will grow at an average growth rate of **5.0%** in twenty-five years (2015-2040) i.e. the overall natural growth will continue and in-migration will gradually increase due to intensive investment. With this assumption, the population of Lamu Island will be expected to grow to **59,949** by year 2040.

Medium Growth Rate: This scenario assumes that the population will grow at a varying growth rate of **4.0%** to **4.3%** in twenty-five years (2015-2040) and that improved medical / health facilities will result in decrease in mortality rate and increase in life expectancy. It is presumed that with economic growth, employment opportunities and improved infrastructure (especially speed transport connectivity) will work in balancing migration. Thus, the projected population within the Study Area of Lamu Island by year 2040 will be **46,436**.

Low Growth Rate: This scenario assumes that the population of Lamu Island will grow at a decreased average growth rate of **3.0%** in the next twenty-five years (2015-2040). It is assumed that population growth (both natural growth rate and in-migration) will reduce considering that population deflection will take place and the flow of return will be diverted to the development of new areas. Therefore, the population in horizon year 2040 will be **33,027**. This can happen only, if strict measures are taken to control population both in terms of natural growth and in-migration. It requires intensive efforts by government in terms of educating people and promoting 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** on **Page 3-3**;

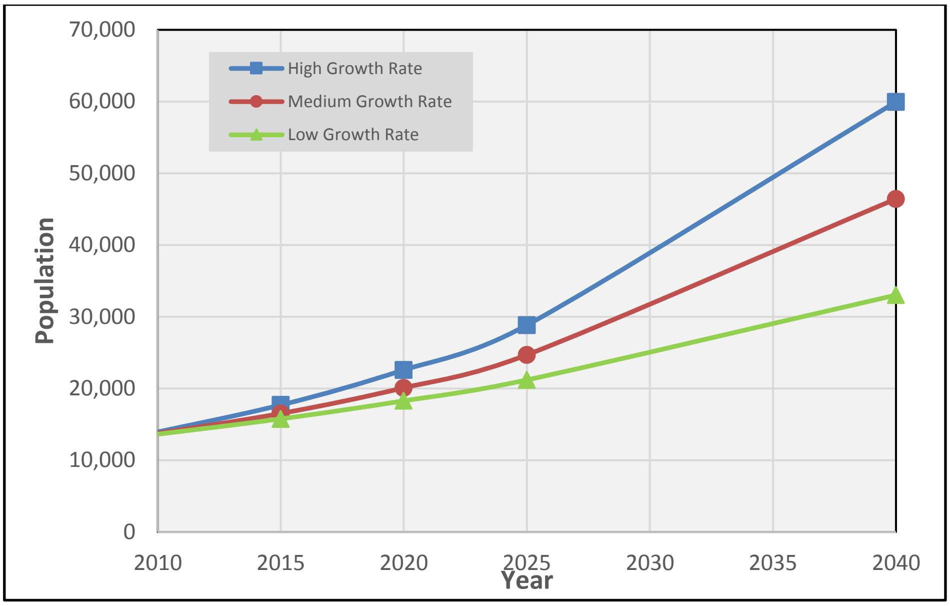


Figure 3.1: Projected Populations based on Growth Rate Scenarios

From **Figure 3.1** above, the population forecast is highly sensitive to population growth rate; high growth scenario results to 29% more the projected population in the medium growth rate scenario while low growth rate results to 29% less the medium growth rate population forecast.

3.1.3 Projected Population for Lamu Island

Lamu Island is the largest urban centre in Lamu County with a high population compared to the adjacent peri-urban and urban areas of the same status because of better infrastructure and more employment opportunities. With more infrastructural projects and industries planned for Lamu Island and its environs, it is expected that Lamu Island will continue attracting immigrants and industrialization opportunities due to the developed infrastructure and land availability.

In consideration of the above foreseen situation, **the medium growth rate scenario considered under the population growth scenario, is the most probable scenario for the future population projections of Lamu Island up to the 2040 design year.** It considers the demographic dynamics between Lamu and neighbouring Towns, possible trends in fertility, mortality and migration levels and patterns as well as the socio-economic development. Besides, it has the net minimal risks associated with under-utilization or overloading of the proposed sanitation system within the design horizon.

Table 3.3 below gives a summary of the projected population for Lamu Island up to the design horizon of year 2040, based on the adopted medium growth rate ranging from **3.8%** p.a to **4.3%** per annum.

Table 3.3: Summary of the Projected Population

Sub-locations	2009	2015	2020	2025	2040
	Growth Rate (%)				
	-	3.8%	4.0%	4.2%	4.3%
Shela	2,579	3,226	3,924	4,821	9,065
Mkomani	3,783	4,732	5,757	7,072	13,298
Langoni	6,849	8,566	10,422	12,802	24,074
Total	**13,210**	**16,523**	**20,103**	**24,695**	**46,438**

3.2 Land Use and Urban Development

3.2.1 Introduction

Lamu Island is the main economic hub of Lamu County due to significant tourism activities. A section of the Lamu Island is Lamu Old Town. This 16-ha area is the oldest and best preserved example of Swahili settlement in East Africa. It is characterized by narrow winding streets (2.4m wide) and unique Swahili architecture demonstrating the cultural influences of European, Arabian, Indian and traditional Swahili techniques producing a distinct culture. Lamu Old Town is a gazetted National Heritage Site managed by National Museums of Kenya. All components are legally protected and any development is strictly controlled.

The proposed Lamu Port and Resort city to be constructed on Manda Bay under the Lamu Port-South Sudan-Ethiopia-Transport (LAPSSET) Corridor Project is expected to boost economic development in Lamu Island. Population growth is expected due to increased tourism arrivals and immigration of workers at the new developments.

Lamu urban area is expected to grow towards the North and South since the Lamu Old Town cannot be developed any further.

Some planning efforts have been made for Lamu Island. The Lamu Management Plan (2007-2013) was prepared to enhance conservation of the value of the town's cultural heritage assets as well as its complementary buffer zone areas (GoK, 2007). In addition, The Lamu County Integrated Development Plan (2013-2017) addresses several issues facing the county such as perennial floods, unreliable rainfall, land fragmentation, climate change among other issues (GoK, 2013). The proposed interventions in the plan include:

- Rehabilitation of flood prone areas
- Control land fragmentation
- Land use planning
- Provision of a waste management system
- Establishment of reforestation programmes etc.

Waterborne diseases are common in Lamu Island due to poor sewerage and storm water drainage. Sewerage is discharged into storm water drains causing high rates of typhoid and dysentery. Most storm water drains are blocked and act as breeding ground for mosquitoes making malaria prevalence high (Onyoncho G, 2013). The poor disposal of industrial wastes, plastics and biomedical wastes is also a cause of diseases in Lamu Island.

3.2.2 Existing Land Use

The main drivers of growth in Lamu are as follows:

i) Tourism

Lamu Island is endowed with tourist attraction sites. Some of them are the Beach, Lamu Old Town with the Lamu Cultural Festival, Maulid Festival, Food and Arts Festival among others. Tourism sector plays a key role in socio-economic growth in Lamu Island through job creation and revenue generation.

ii) Proposed Lamu Port and Resort City Development

The Proposed Lamu Port at Manda Bay and its associated development such as International Airport, Resort city, Oil refinery, etc. will foster rapid economic development in Lamu Islands.

Figure 3.2 on **Page 3-5** shows the existing Land Use Plan of the area of interest in Lamu Island.

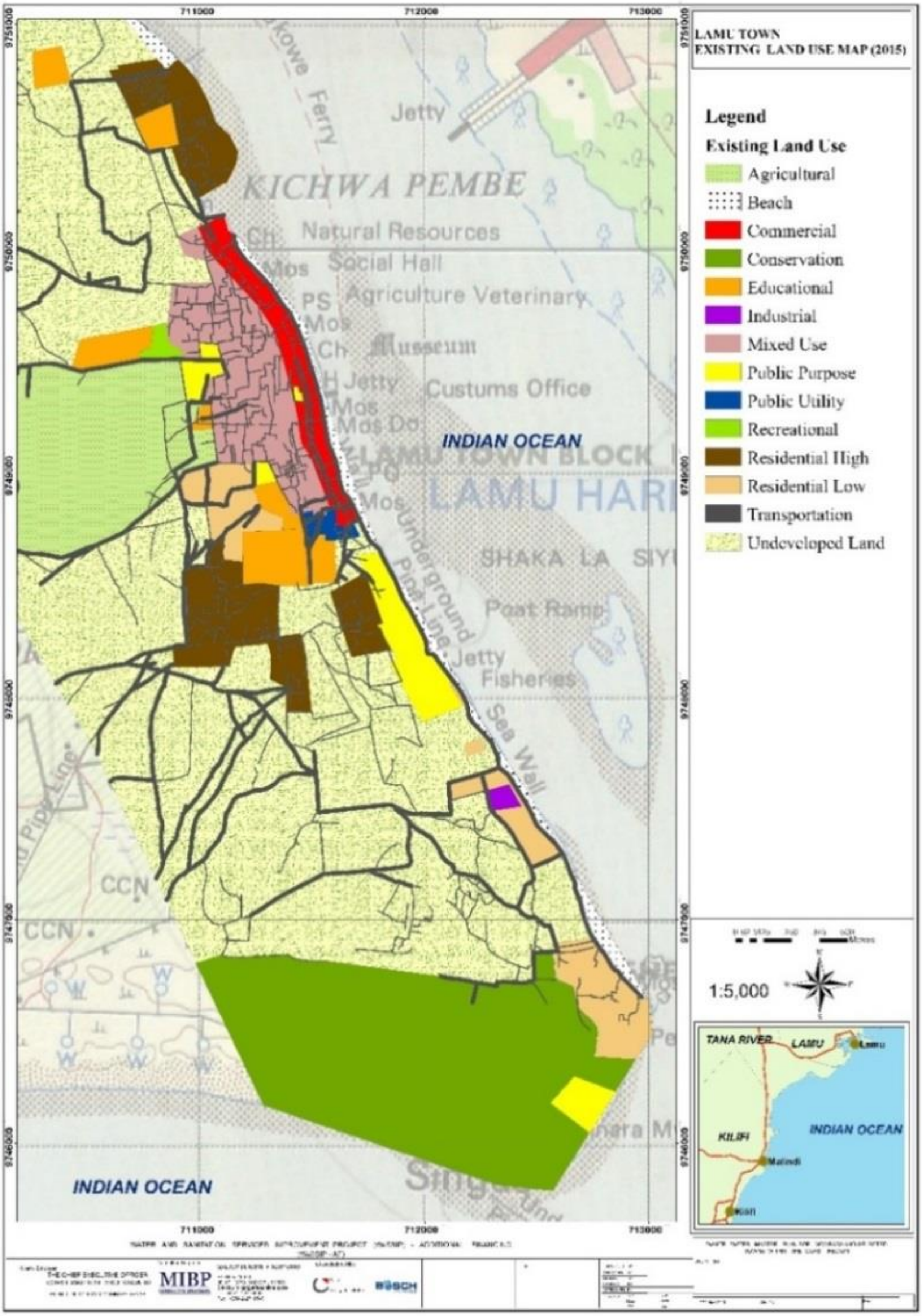


Figure 3.2: Existing Land Use Map of Lamu Island

It's evident from the Existing Land-Use Plan that the dominant land uses in Lamu are Agricultural and Residential Land-use. The total area of Lamu coverage area is approximately 131 ha. The types of land-uses evident within Lamu are mainly residential, recreational, transportation, public purpose, educational, industrial, and commercial among others.

Residential Land-use covers a total land area of 66.48 ha, followed by educational land which covers 22.86 ha. Industrial land use is the least dominant land use covering 1.22 ha.

Table 3.4 below shows a summary of existing Land Use.

Table 3.4: Summary of Existing Land Use.

Land use	Size(ha)	%
Residential high	39.07	29.84
Residential low	27.41	20.93
Commercial	15.85	12.10
Public purpose	19.80	15.12
Educational	22.86	17.46
Public utility	2.24	1.71
Industrial	1.22	0.93
Recreational	2.50	1.91
Total	**130.95**	**100**

The growth constraint in Lamu Island is Lamu Old Town which is a UNESCO National Heritage Site and any new development in the Lamu Old Town is highly regulated by the Government. The existing housing and infrastructure should be retained and no significant development is expected in the Old Town. Expansion of the town will take place inland, away from the beach.

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 **46,438** in Year 2040 **(**Refer to **Table 3.3** on **Page 3-3)** are proposed to be accommodated within the coverage of Lamu Island without any expansion.

It is also proposed that the existing undeveloped land be utilised (including a small part of agricultural land and part of hilly terrain at low height where the slope is gentle and favourable) for development and accommodating part of the projected population.

3.2.4 Land Use Requirement per Land Use Zone

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

In most Towns, Residential Land-use has the highest land requirement. The current coverage of Residential Land-use is approximately **66.5 ha** and is expected to increase to **80.8 ha** in Year 2040 to accommodate the increasing population in all the various housing densities.

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, the potential of the developed areas for densification 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 requirements are given in **Table 3.5** below.

Table 3.5: Existing and Projected Land Use

Land Use	Existing Land Use 2015 (Area, ha)	Projected Land Requirement 2040 (Area, ha)
Residential high	39.07	47.97
Residential low	27.41	32.90
Commercial	15.85	18
Public purpose	19.8	23.77
Educational	22.86	27.44
Public utility	2.24	2.69
Industrial	1.22	1.47
Recreational	2.5	3
TOTAL	**130.95**	**157.24**

The development pattern evident in the town is growth towards the North and South while there is minimal growth towards the hinterland. Commercial developments are concentrated along the shoreline. Residential developments at the northern part of the town will fill the gap between existing settlements. Poor state of roads in the hinterland is the main factor limiting growth of Lamu Island towards the hinterland. The Town's growth towards the South is also limited by the sand dunes. The sand dune is the main source of fresh water for fishing in Lamu County.

Lamu Island lacks an Integrated Strategic Urban Development Plan (ISUDP). It is essential to prepare the Town's ISUDP to promote sustainable and orderly development. The ISUDP should ensure consolidation and reservation of land for future use. The reserved land will accommodate the projected land uses as detailed in **Table 3.5** above.

The ISUDP should also aim at enforcing development control, establishing adequate, decent and affordable housing, conservation of the green spaces and the environment and provide a road map for provision of services and facilities.

Layout Plans showing the Proposed Land Use Plans for Year 2025 and 2040 are given in **Figures 3.3** and **3.4** on **Pages 3-8** and **3-9** respectively**.**

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

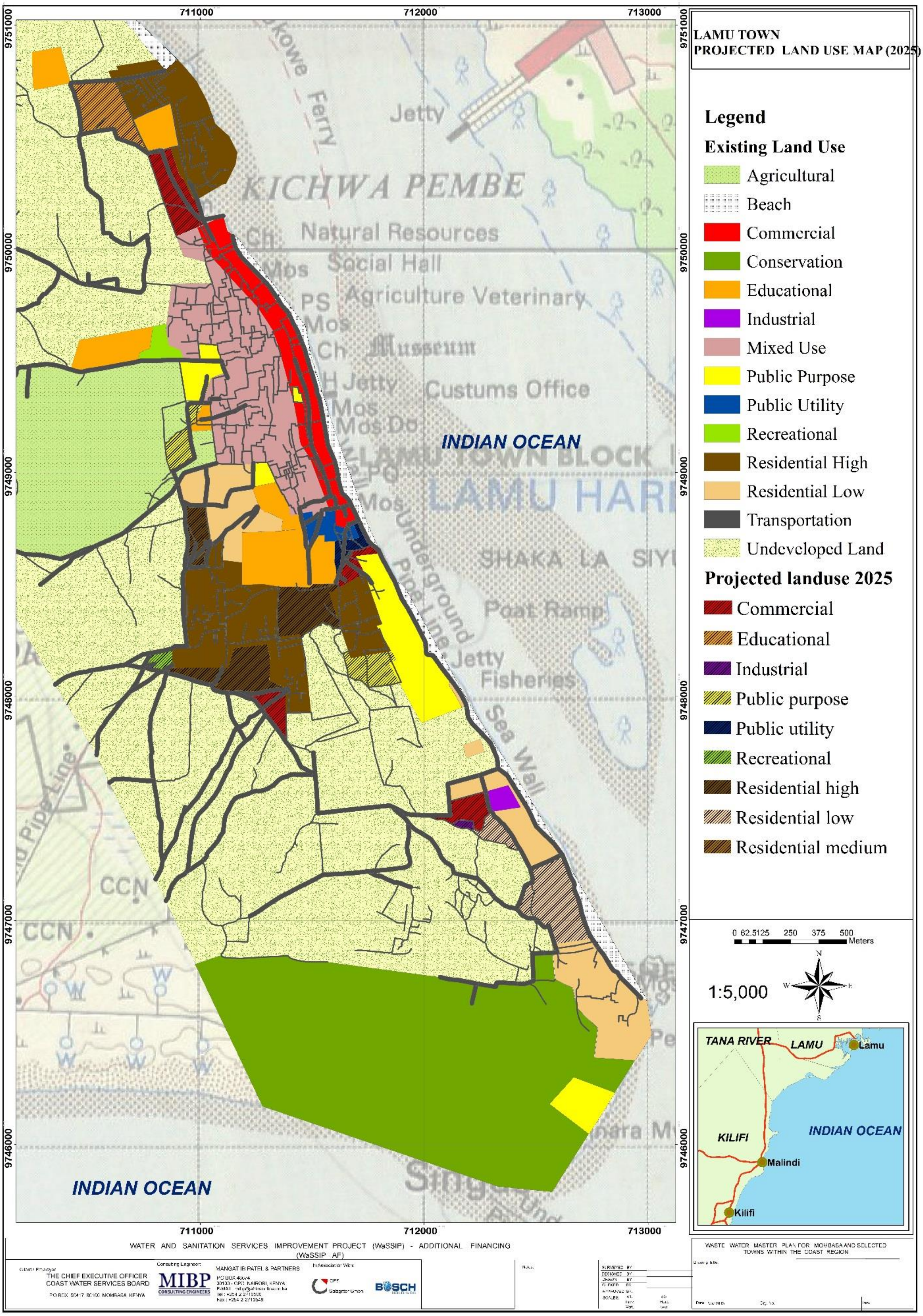


Figure 3.3: Projected Land Use Year 2025

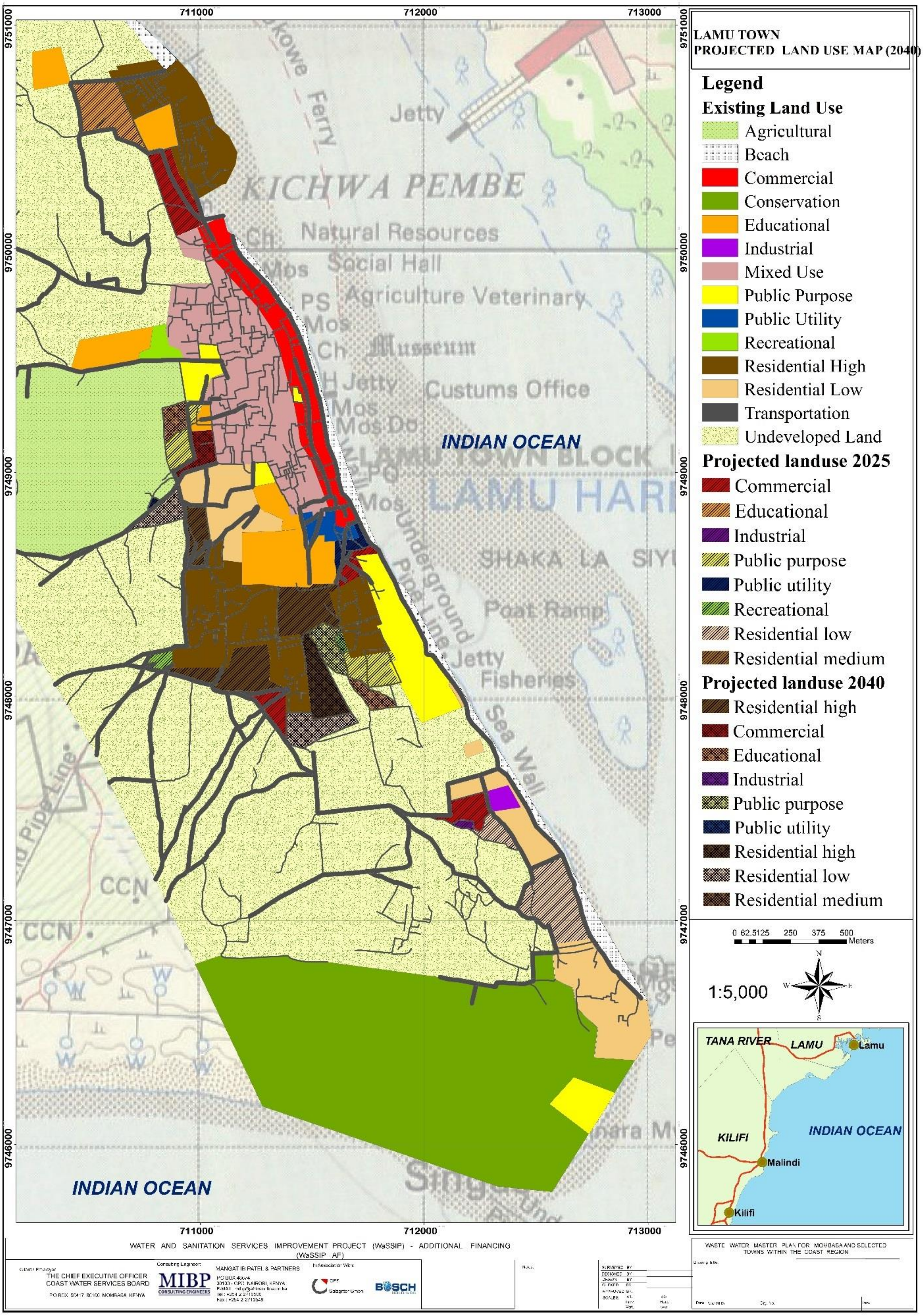


Figure 3.4: Projected Land Use Year 2040

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 in 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

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						

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
H								
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.

The total water demand can be expressed as follows;

$$\textbf{Total water demand}$$

$$= \textbf{Domestic demand} + \textbf{Institutional demand} + \textbf{Commercial demand} + \textbf{Industrial demand} + \textbf{Tourism Recreation demand}$$

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

A summary of the Studies / Designs prepared by the various Consultants for Water Supply in Lamu is given below:

- Gauff Ingenieure/TRAQ finalised Detailed Design Report for Lamu Water Service Provider, October 2010
- BRL Ingenieure/ GIBB Africa – Feasibility Studies/ Identification of Institutional Support (Lamu)

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**.

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)		
BRL Ingenieure/ GIBB Africa	Lamu WSP Area - Feasibility Studies/ Identification of Institutional Support - October 2008	200	80	50	10	5	10	5	5,000 – 20,000
Gauff Ingenieure/ TRAQ	Detailed Design Report - Lamu WSP - October 2010 (REV 2)	200	120	60	42	21	333	25 - 500	25,000
Ministry of Water and Irrigation (MWI, 2008)	Design Manual for Water Supply in Kenya (MWI, 2008	250	150	75	50	25	400		20,000

After analysis of the water consumption rates indicated in **Table 4.1** on **Page 4-2**, the following water consumption rates have been adopted in the Study:

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 capita demand observed in similar socio economic and climatic context but without restriction of water supply, the Consultant adopted the following water consumption rates for the various categories of domestic consumers 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)	60

b) Institutional Water Demand

The institutional water demand has been determined based on the following commonly accepted demand criteria by type of institution:

- Boarding Schools - 50 l/head/d
- Day School with WC - 25 l/head/d
- Regional Hospital - 200 l/bed/day plus 5000l/day
- Dispensary and Health Centre - 5000 l/day
- Administrative Offices - 25 l/head/day

c) Commercial Water Demand

The commercial water demand has been determined 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 has been 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 has been 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

Lamu Island is likely to grow rapidly over the design horizon period (up to 2040) due to improved infrastructural network within the rest of the County and potential for new settlements. The Towns absorbs a large portion of the population growth in the County through increased housing density, infilling and new development. This is further compounded by the prominent tourist industry in the Town.

The water demand for Lamu Island in 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 for Lamu Island by sub-location in Design Horizons Year 2025 and 2040 is given in **Tables 4.3** and **4.4** below.

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

Sub-locations	Water Demand (m^3/day)						
	Domestic	Health	Education	Recreational	Commercial	Industrial	Total
Shella	308.7	77.5	22.4	6.6	10.3	17.8	443.3
Mkomani	996.0	250.0	72.2	21.3	33.3	57.3	1,430.1
Langoni	1,385.4	347.8	100.4	29.7	46.3	79.8	1,989.4
Total	**2,690**	**675**	**195**	**58**	**90**	**155**	**3,863**

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

Sub-locations	Water Demand (m^3/day)						
	Domestic	Health	Education	Recreational	Commercial	Industrial	Total
Shella	580.5	145.7	42.1	12.4	19.4	33.4	834
Mkomani	1,872.9	470.2	135.8	40.1	62.5	107.8	2,689
Langoni	2,605.3	654.1	188.9	55.8	87.0	150.0	3,741
Total	**5,059**	**1,270**	**367**	**108**	**169**	**291**	**7,264**

The water demand projection for Lamu Island is shown in **Figure 4.1** below.

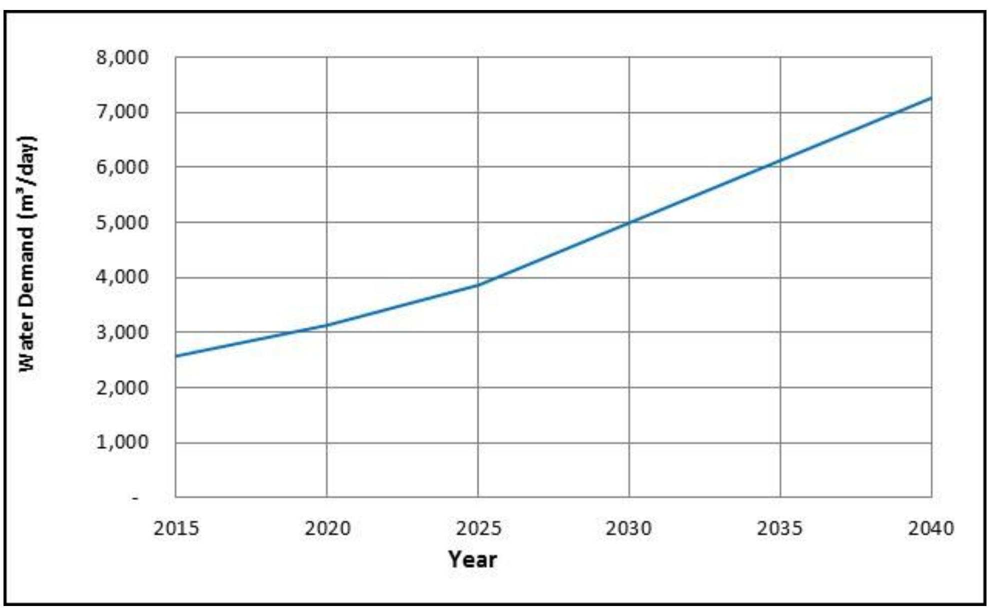


Figure 4.1: Water Demand Projection

5.0 WASTEWATER FLOW PREDICTIONS

5.1 Design Criteria

The determination of the wastewater flows adopted in the design of the Sewers and Wastewater Treatment Plant for Lamu Island has been guided and based on the Standard design criteria described in the following sub-sections;

5.1.1 Principal References

In Kenya, it has become 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 Lamu Island 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 Lamu Island.

5.1.3 Sewage Generation

Wastewater 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

Sewage contribution factor varies from 75% to 85% of water supplied, depending on the 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 other 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, where they apply, will increase significantly.

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, the sub-soil conditions, the workmanship during construction, the age and condition of the pipes, and the frequency of occurrence of improper connections. Another significant factor is the condition and depth of manholes; where covers are damaged or missing, or where the ground surface level is above cover level, then surface water runoff enter the sewer as inflow.

For the design of the sewers in Lamu Island, 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.

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", a provision which allows for unavoidable storm water entry and 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 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:

$$\text{DWF} = \text{SF}\left[\left(\frac{\text{P x G}}{86400}\right) \text{x} \left(\frac{1+\text{SA}}{100}\right) + \frac{\text{E x}\,\text{A}_\text{E}}{86.4} + \text{I}_\text{R}\,(\text{A}_\text{P} + \text{A}_\text{E})\right]$$

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 Wastewater 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
< 6.0	7.5
< 12.0	6.6
< 60.0	5.5
< 120.0	5.0
< 600.0	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	$Peak\ Factor = \frac{6.51}{Population^{0.38}}$
Babbitt Formula, for population < 7,000 Persons	$Peak\ Factor = \frac{5}{Population^{0.2}}$
Harmon Formula, for population > 7,000 Persons	$Peak\ Factor = 1 + \frac{14}{4 + Population^{0.5}}$

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 Lamu are as follows;

- Babbitt 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 Lamu Island has been determined and is given in **Table 5.4** below;

Table 5.4: Projected Wastewater Generation up to Year 2040

Study Area	Area (Ha)	Wastewater Generation (m^3/d)				
		2009	2015	2020	2025	2040
Shella	230.2	660	1,217	230.2	660	1,217
Mkomani	265.7	968	1,786	265.7	968	1,786
Langoni	207.3	1,752	3,233	207.3	1,752	3,233
Total	**703**	**3,379**	**6,236**	**703**	**3,379**	**6,236**

However, achieving conditions of regular / unsuppressed water supply and full sewer connections in a Town with Sewerage System is nearly impossible. This is caused by the limited development of water resources to serve Lamu, inadequate water distribution and sewerage networks and the 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 **Tables 5.5** and **5.6** below, have been adopted for the formulation of realistic wastewater generation projection for Lamu Island.

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;

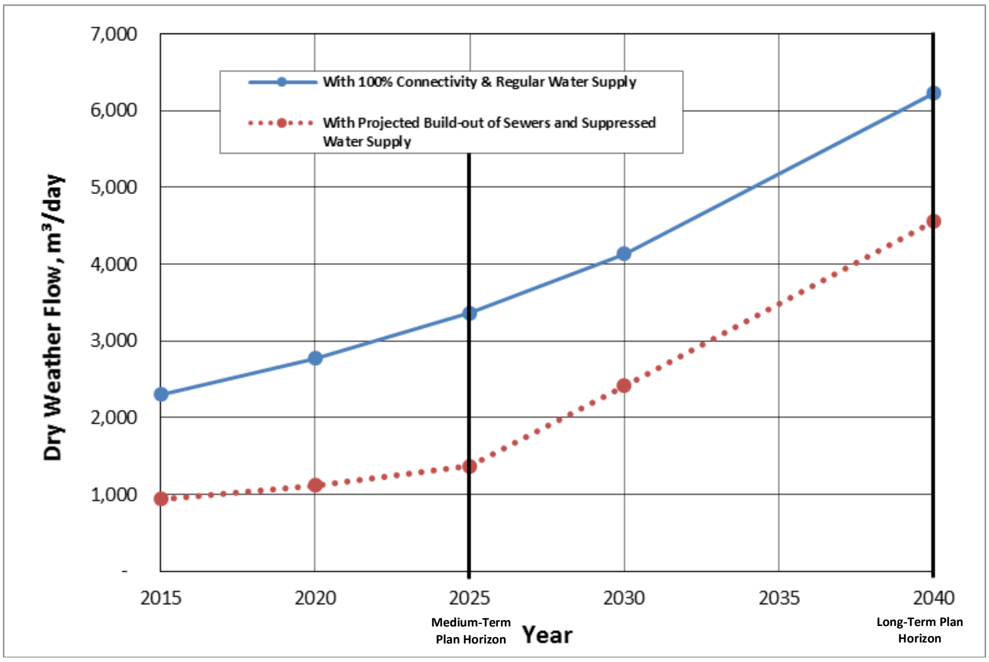


Figure 5.1: Projected Wastewater Flows up to Year 2040

From **Figure 5.1** above, the projected wastewater generation, based on the realistic conditions of suppressed water supply and gradual implementation of sewer connections, in the Years 2025 and 2040 is 1,400 m^3/day and 4,600 m^3/day respectively.

The design of 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-up 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. However, individual house connections of 150mm diameter is sufficient.

This recommendation is comparable to that of WHO Report No. 9; 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 Lamu 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 shall 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. The 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 accurate answer, 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)

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 equation has been adopted for the design of gravity sewers. It has been complimented by Design Tables and Charts for the Colebrook-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 Lamu Island 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 sewers and is inappropriate for house connections or the secondary sewers for Lamu Island where flows may be intermittent and retention times short. A minimum velocity of 0.75 m/s has been adopted with exception of some critical circumstance where a velocity of 0.6 m/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 and Irrigation Practice Manual for Sewerage and Sanitation Services in Kenya (2008) explains that maximum flow velocities were previously specified to reduce possibilities of erosion in the pipe internal linings through scouring effects. Such effects were said to occur at flow velocities exceeding 4.0 m/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 velocity guidelines 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 flow in exceptional circumstances 6.0 m/s

6.1.4 Sulphide Generation

Hydrogen sulphide is the main source of corrosion in 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 wall of sewer pipe and result to corrosion of ferrous and concrete walls causing their 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 Lamu Sewerage System, 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 is required to ensure protection against damages 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 lead to unnecessarily deep sewers. However, additional protection can be provided at the upstream section of sewers if shallow depths are adopted to limit sewer depths and 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 Lamu Island 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 for the various sewer pipe diameters have been adopted based on the guidelines of the 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 Sewerage System for Lamu 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
- Cost of materials and installations

Due to the various requirements in the Sewerage System for Lamu, 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. Most contractors are also experienced in handling uPVC pipes. In addition, 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. This is 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 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 against corrosion attacks and overburden.

iii. HDPE Pipes

HDPE pipes are ideal for many different applications including municipal, industrial, energy, geothermal, landfill and more. HDPEs pipe are 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 pipes are also a more environmentally sustainable option as they are non-toxic, corrosion and chemical resistant, have long design life, and are ideal for trenchless installation methods owing to their 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 sewer pipe material.

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. The high cost of steel pipes also discourages their 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 inevitable for aerial river crossings, pumping mains, high impact resistance and bridging ability; either spun iron or mild steel pipes can be used. Standardisation of pipe materials and fittings within the jurisdiction of LAWASCO has also been considered.

The Gravity Sewers for Lamu Island 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 LAWASCO'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 shall 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.

As per the *Final Practice Manual for Sewerage and Sanitation Services in Kenya (MWI, 2008),* the following types of pumps are considered most suitable for sewage works in Kenya: -

i. Solids diverters (flows of 360 l/min or less),
ii. Submersible pump-sets incorporating centrifugal pumps (450 - 2,500 l/min),
iii. Centrifugal pumps (2,500 – 18,200 l/min),
iv. Mixed -flow pumps (above 18,200 l/min).

However, where the public can be excluded, screw pumps are considered suitable for sewage "lift" stations. 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.

Apart from solids diverters, submersible pump-sets 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, "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, considerable extent, dictated by the type of plant. 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 a Wet Well or Dry Well. Both types of station 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) Wet Well Stations (Submersible Pumping Stations)
b) Dry Well Stations (Wet Well / Dry Well Pumping Stations)
c) Packaged Pumping Stations e.g. Screw Pumping Stations

Wet Well Stations

At such stations, the pumps are installed in the substructure or Wet Well which contains sewage. 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.

In 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 in Kenya, for pumping capacity within the range 450 – 2,500 l/min. This guideline has not been stringently followed in this study.

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 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. All Sewage Pumping Stations should therefore 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 ditch or pond.

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 design period of 20 years.

Sewage Pumping Stations with screw pumps or 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 diverters, this formula results in design flows of 450 l/minute or more, then centrifugal pumps rather than 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 Criteria for Treatment 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 system 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;

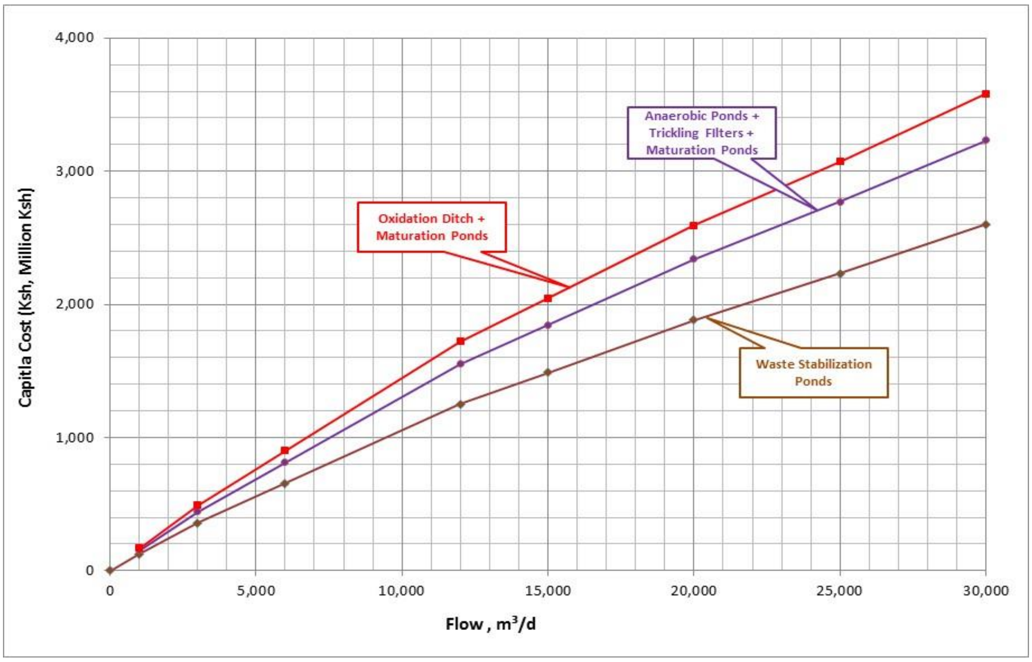


Figure 6.1: Capital cost for different wastewater treatment technologies

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 land requirements for the various treatment technologies.

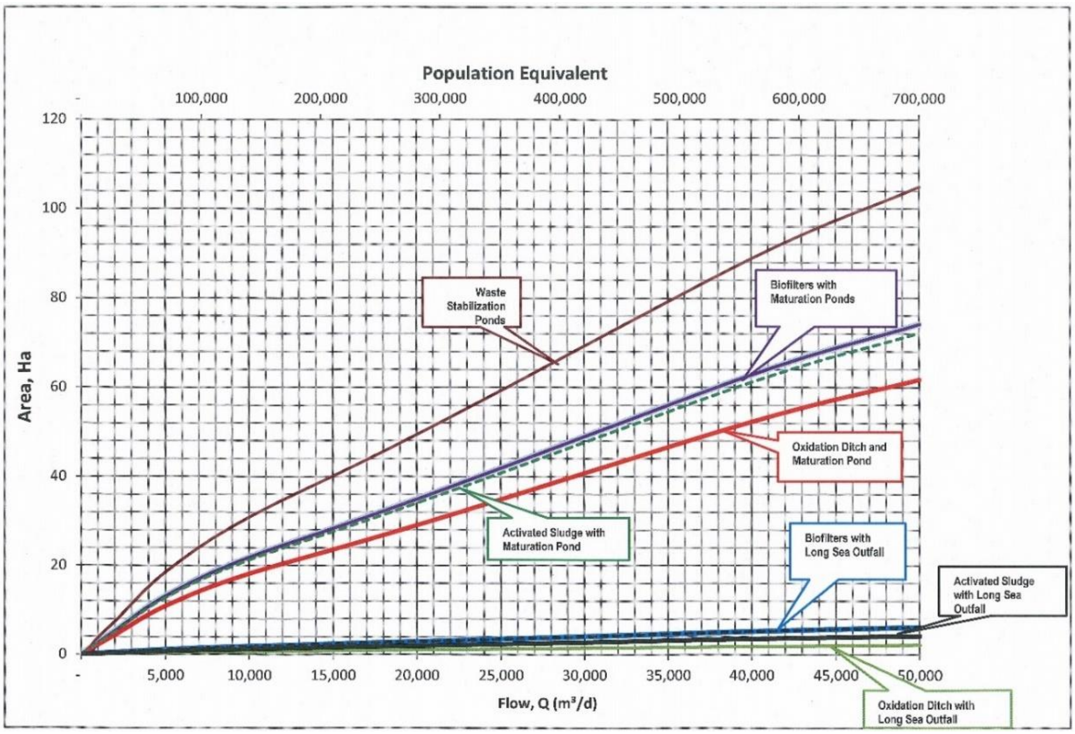


Figure 6.2: Land Requirements for the various Treatment Technologies

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 process. Some wastewater treatment technologies such as the Activated Sludge has a dominant anaerobic digestion process 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 Wastewater 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 Wastewater Treatment Plant to the build-up areas.

6.3.2 Alternative Wastewater Treatment Processes / Technologies

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

i) <u>Waste Stabilization Ponds</u>

Application Level:	Management Level:	Inputs: Blackwater, Brownwater, Greywater, (Sludge)
Household	Household	Outputs: Effluent, Sludge
Neighbourhood	Shared	
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;

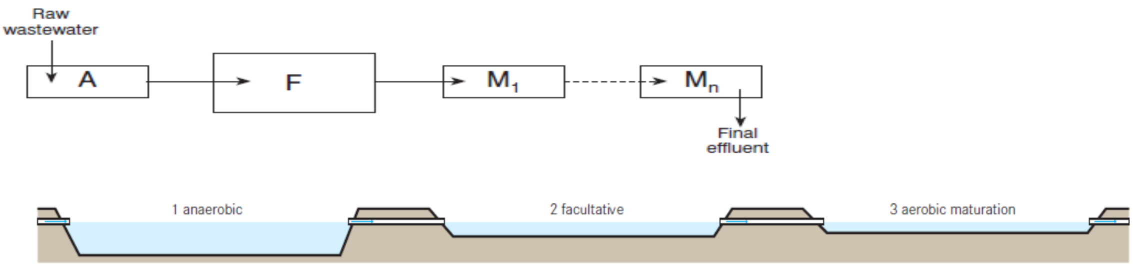


Figure 6.3: Layout of Waste Stabilization Ponds

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

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

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.

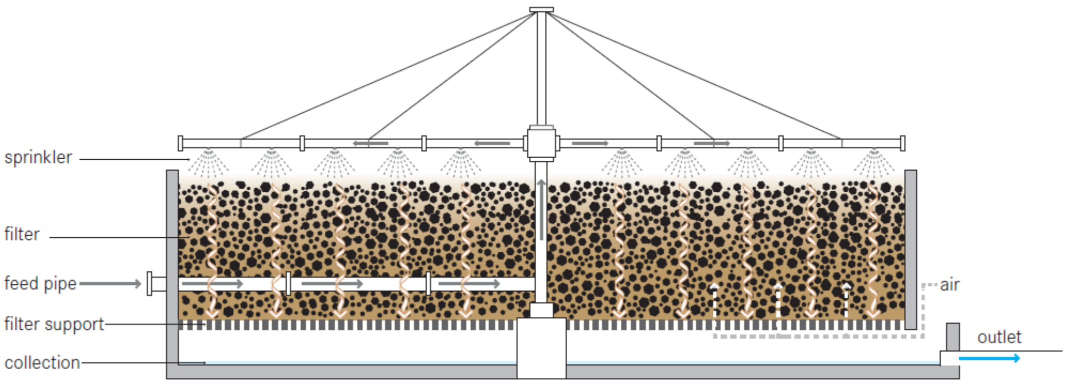


Figure 6.4: Sectional View of a Circular Biofilter

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 at small footprint & less 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	Outputs: Effluent, Sludge
Neighbourhood	Shared	
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, Brownwater, Greywater
Household	Household	Outputs: Effluent, Sludge
Neighbourhood	Shared	
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).

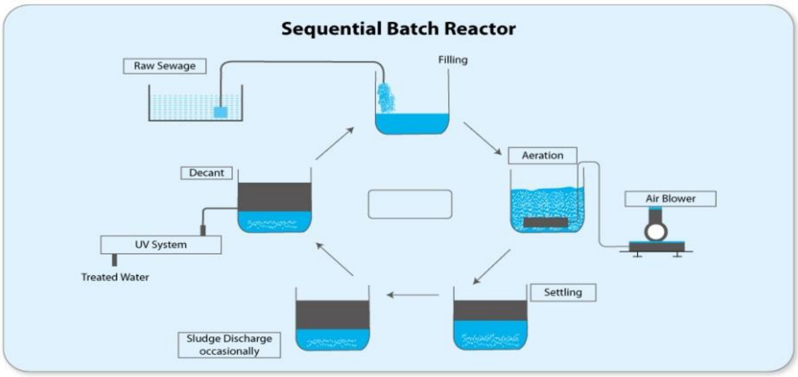


Figure 6.5: Schematic Showing SBR operational cycle

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 over-emphasized 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 Wastewater 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 mat 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 considered in the selection of WWTP location are briefly discussed below.

i. Land-Use

In the Land-use Map, different areas of Hola 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.

ii. 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.

iii. 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.

iv. 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.

v. 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 Hola 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.

vi. 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.

vii. 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.

viii. 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 Delineation of Drainage Areas

The Sewerage System for Lamu Island 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 eighteen (18) drainage areas have been formulated in the study area of Lamu Island.

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

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

Drainage Area No.	Coverage (Ha)	Year 2025		Year 2040	
		DWF (m^3/d)	BOD_5 (mg/l)	DWF (m^3/d)	BOD_5 (mg/l)
1	6.24	19.9	586	64.9	589
2	18.82	46.0	538	150.5	545
3	9.74	14.5	651	46.5	654
4	9.55	14.1	654	46.5	657
5	50.49	45.1	521	144.6	536
6	227.32	489.4	554	1607.6	559
7	83.32	287.0	649	953.9	650
8	46.22	109.7	546	363.7	550
9	6.84	38.5	792	129.1	792
10	31.33	57.1	539	189.6	543
11	13.4	24.0	570	79.7	571
12	12.08	16.6	506	53.1	517
13	8.59	12.4	519	40.6	528
14	17.39	22.4	506	73.0	518
15	14.4	19.0	508	61.2	520
16	33.52	40.6	496	131.3	511
17	113.32	132.9	493	429.4	509
18	6.85	10.8	543	34.7	550
Mean	**-**	**-**	**565**	**-**	**572**
Total	**709.4**	**1,400**	**-**	**4,600**	**-**

The Projected Dry Weather Flow for the study area of Lamu Island at the Design Horizon (Year 2040) is approximately **4,600 m^3/day**.

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

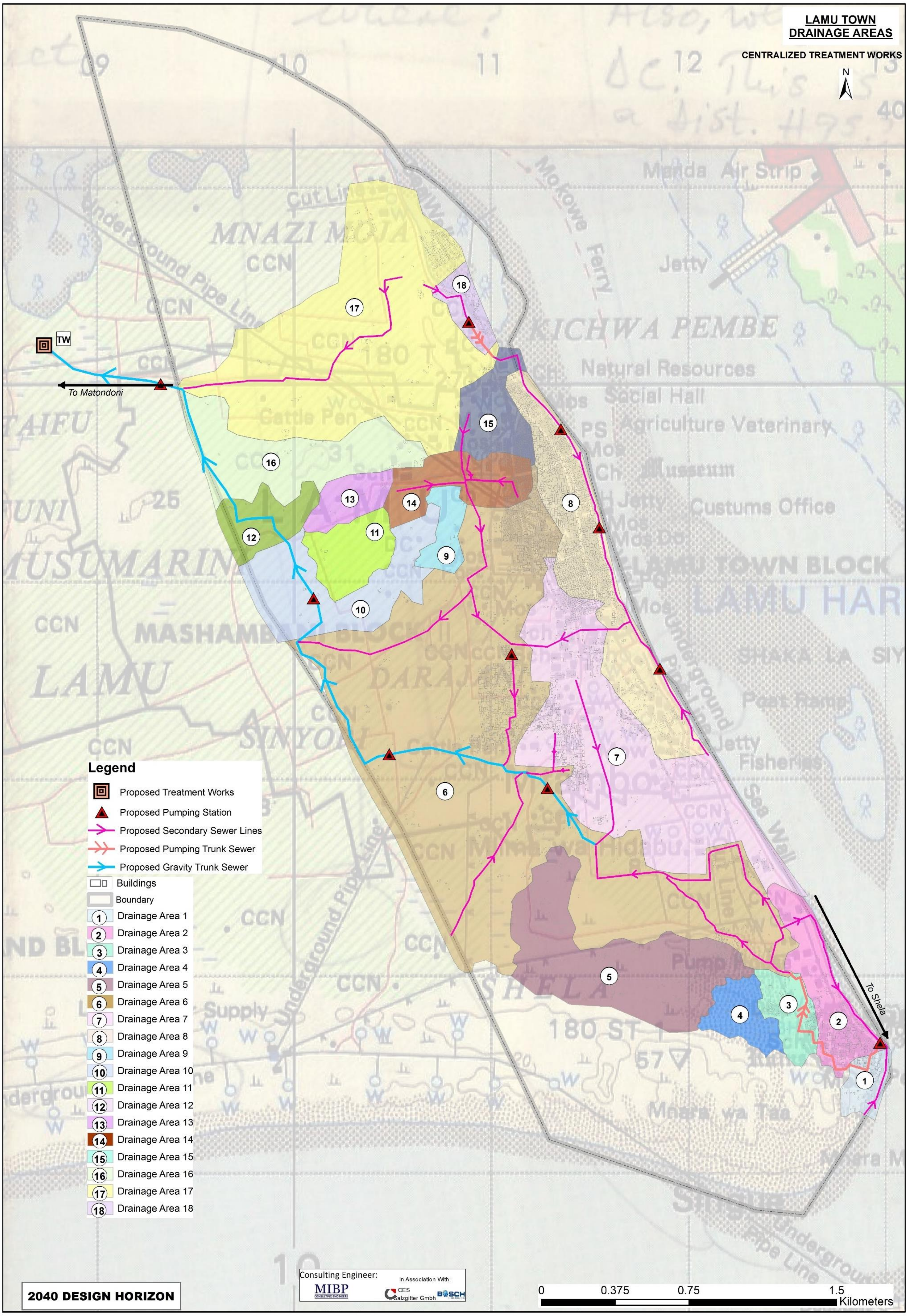


Figure 7.1: Proposed Drainage Areas

7.2 Description of Proposed Wastewater Management Scheme

The definite topography of Lamu Island has limited the feasible site for the development of Wastewater Treatment Plant to a single low point at undeveloped site located at Taifu area.

This site has been selected after evaluation of pertinent physical, environmental and economic considerations including the ease with which wastewater generated from Lamu Island can be conveyed by gravity to the site with minimum pumping, land availability in this un-developed area and its safe distance from the built-up areas.

From preliminary investigations, the site is only suitable for the construction of Waste Stabilization Ponds. Thus, a single Wastewater Management Scheme has been formulated for Lamu Island i.e. **Centralized Scheme with a Wastewater Treatment Plant at Taifu area.**

This centralized scheme involves Trunk and Secondary Sewers, Pumping Stations and a Wastewater Treatment Plant with an ultimate design capacity of 4,600 m^3/day.

A full conventional Wastewater Treatment Plant, encompassing Waste Stabilisation 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

Based on the recommended treatment technology (WSPs) and the ultimate projected wastewater flows under realistic conditions of water supply and sewer connections, the land required for the construction of the Wastewater Treatment Plant to serve the sanitation needs of Lamu Island up to the ultimate horizon of year 2040, is approximately **15 Ha.**

A summary of the proposed wastewater management scheme for Lamu Island is given in **Table 7.3** below.

Table 7.2: Summary of Proposed Wastewater Management Scheme

Conveyance System			Wastewater Treatment Plant			
Secondary and Gravity Trunk Sewers (km)	Pumped Sewers (km)	No. of Pumping Stations	Location	Design Capacity (m^3/day)	Treatment Technology	Land Required (Ha)
20	1.3	2	Taifu area	4,600	Waste Stabilization Ponds	15.0

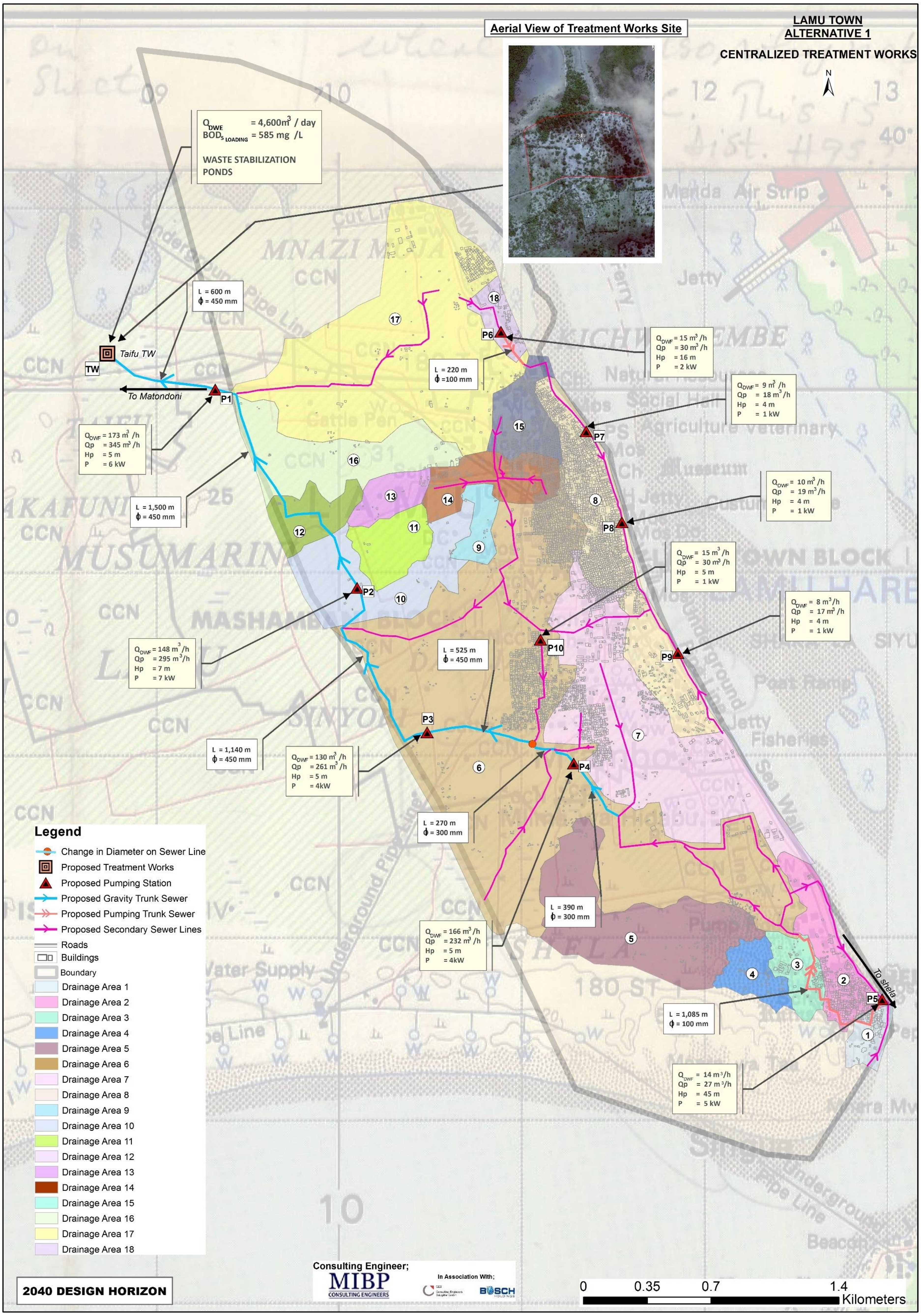


Figure 7.2: Proposed Wastewater Management Scheme

8.0 PROJECT COSTS OF THE PROPOSED WASTEWATER MANAGEMENT SCHEME

8.1 Introduction

This Chapter describes the Project Costs of the Proposed Wastewater Management Scheme formulated to serve the sanitation needs of Lamu Island 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. <u>All the unit costs are inclusive of relevant duties and taxes but not Preliminary and General Items, Contingencies and Consultancy Fees.</u>

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 Investments

8.2.1 Basis of Cost Estimates

Capital costs represent the total expenditures 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 material, 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 (i.e. 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 Lamu Island depends on the proximity to services and market forces. The average costs of land adopted for the Wastewater Master Plan in Lamu Island is **Kshs. 5,000,000 per ha** after comparison and assessment of the information of cost of land within the Urban Centre 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

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

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

- Supply of all materials to site
- Pipe lay, joint with rubber rings, granular bedding, test and backfill of trench for flexible-jointed 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 for 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	1205	1473
300	278	417	696	1071	1377	1683
375	313	469	782	1205	1549	1894
450	348	522	869	1339	1721	2104
525	383	574	956	1473	1894	2314
600	417	626	1043	1607	2066	2525
675	452	678	1130	1741	2238	2735
750	487	730	1217	1874	2410	2946
825	522	782	1304	2008	2582	3156
900	556	835	1391	2142	2754	3366

Hard rock - 3200/= per cubic metre
Soft rock - 1800/= per cubic metre

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

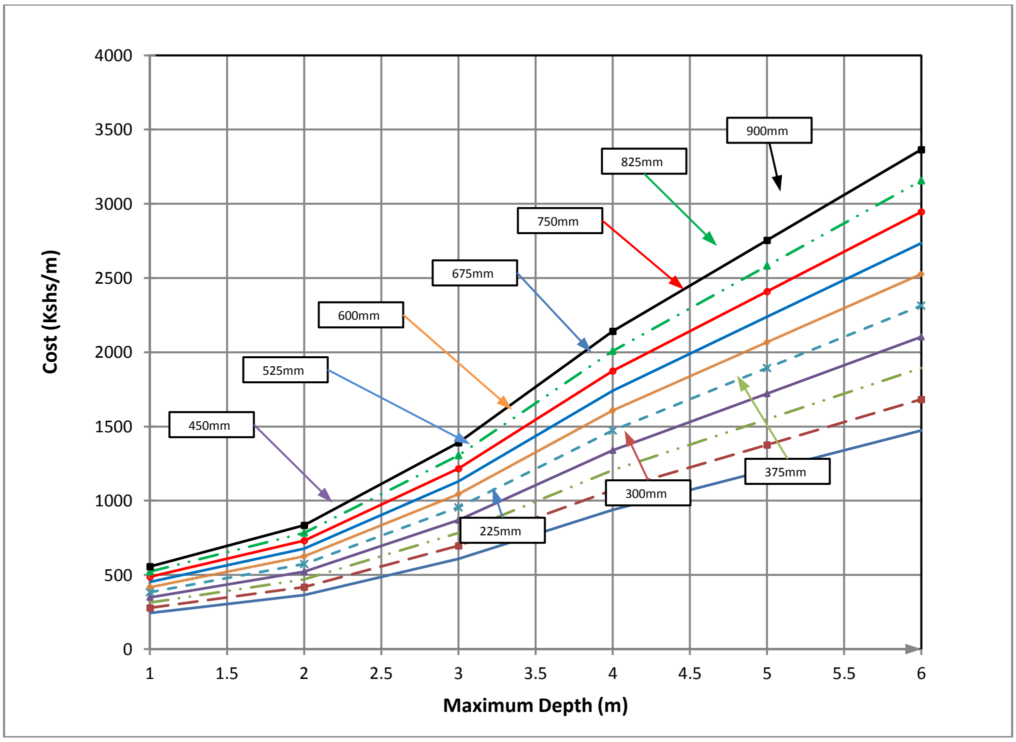


Figure 8.1: Unit cost for sewer excavation with Depth

Unit costs considered for Manholes or for any Pumping Station forming part of the Sewer Network are given in **Tables 8.3** to **8.8** below and **Table 8.9** on **Page 8-5**.

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	1800
4) excavate in hard rock (E.O)	m^3	3200
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, kerns, 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. Biofilters / Trickling Filters	%	20
3. Activated Sludge	%	35
4. Long Sea Outfalls	%	10
5. Activated Sludge	%	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) is a very important factor in the selection of the most suitable 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.

8.3.1.1 Equipment Maintenance and Repairs

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

8.3.1.2 Power Charges

The cost of power consumed has been calculated based on a unit cost rate of Kshs. 18 per kilo watt-hour (kWh).

8.3.1.3 Chemical Costs

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

No chemical is required in the treatment of wastewater since the treatment technology selected is Waste Stabilization Pond which is purely natural and biological.

8.4 Capital and Operations & Maintenance Costs of the Proposed Scheme

8.4.1 Capital Costs

The Capital Cost for the proposed Wastewater Management Scheme formulated for Lamu Island 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%

A summary of the Capital Costs for the Proposed Wastewater Management Scheme is given in **Table 8.10** below;

Table 8.10: Capital Costs for Proposed Scheme

S/No.	Component	Cost, Kshs	Cost, USD [1]
1	**Land Acquisition (Kshs)**	**75,000,000**	**728,155**
2	**Civil Works (Kshs)**	**850,817,517**	**8,260,364**
2.1	Sewage Treatment Plant (Kshs)	459,948,335	4,465,518
2.2	Pumping Stations (Kshs)	58,000,009	563,107
2.3	Sewers (Kshs)	332,869,174	3,231,740
3	**Electro-Mechanical Works (Kshs)**	**62,874,480**	**610,432**
3.1	Sewage Treatment Plant (Kshs)	24,207,807	235,027
3.2	Pumping Stations (Kshs)	38,666,673	375,405
	Total Capital Cost (Kshs)	**988,691,997**	**9,598,951**

8.4.2 Operations and Maintenance Costs

The Operations and Maintenance Costs for the three Alternative Schemes formulated for Lamu have been worked out on the following basis;

d) Electricity Costs at the Pumping Stations has been assumed to increase annually at a reducing rate of 4.0% p.a in 2020 to 4.3% p.a in 2040 (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 Proposed Scheme in the first year of operation is given in **Table 8.11** below;

Table 8.11: Annual Operations & Maintenance Costs for Proposed Scheme (Year 1)

S/No.	Component	Cost, Kshs	Cost, USD [1]
1	Maintenance Costs (Kshs)	11,651,899	113,125
2	Electricity Costs (Kshs)	717,428	6,965
3	Staff Costs (Kshs)	5,064,000	49,165
	Total O&M Cost	**17,433,327**	**169,256**

[1] – Exchange Rate: 1 USD = 103 Kshs

8.5 Average Incremental costs of the Proposed Scheme

Net Present Value (NPV) is a one of the commonly used criteria for comparing economic viability of Alternative Schemes or Separate Schemes to inform financing. 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 Proposed Scheme has 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 2nd year of Implementation of the Medium-Term Plan Works (2022) and thus, scheme operation to commence in the 3rd year (2023)

From the NPV, Average Incremental Cost has been calculated in consideration of the following factors;

- Treated Wastewater to increase from 1,200 m³/d in year 2023 to 4,600 m³/d in year 2040
- BOD removal as the key performance indicator
- Average Influent BOD_5 of 500 mg/l and Effluent BOD_5 of 30 mg/l; thus, BOD_5 removal of 470 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 Proposed Schemes are given in **Table 8.12** below;

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

Performance Index	
NPV (USD)	Average Incremental Cost of BOD Removal (USD / ton of BOD removed)
12,690,827	1,334

8.6 Sensitivity Analysis

To ascertain the susceptibility of the Net Present Values, sensitivity analysis of the Scheme 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 Proposed Scheme

Performance Index	No Variation in CAPEX & OPEX	Change in CAPEX (Capital Expenditures)		Change in OPEX (Operations Expenditures)	
		-20%	+20%	-20%	+20%
Net Present Value, NPV (USD)	12,690,827	10,482,169	14,899,486	12,159,149	13,222,506
Average Incremental Cost of BOD Removal (USD/ ton of BOD Removed)	1,334	1,101	1,566	1,278	1,389

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 Lamu Island.

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 several 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 Lamu 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	Equally importance	Two activities contribute equally to the objective
3	Moderately 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

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

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 Lamu Island. 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 following subsection with their characteristics and influence on the Treatment Train selection 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 years' 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 skills of staff, Operations and 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 for Lamu Island 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)

9.2.4 Hierarchy Decision Model

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

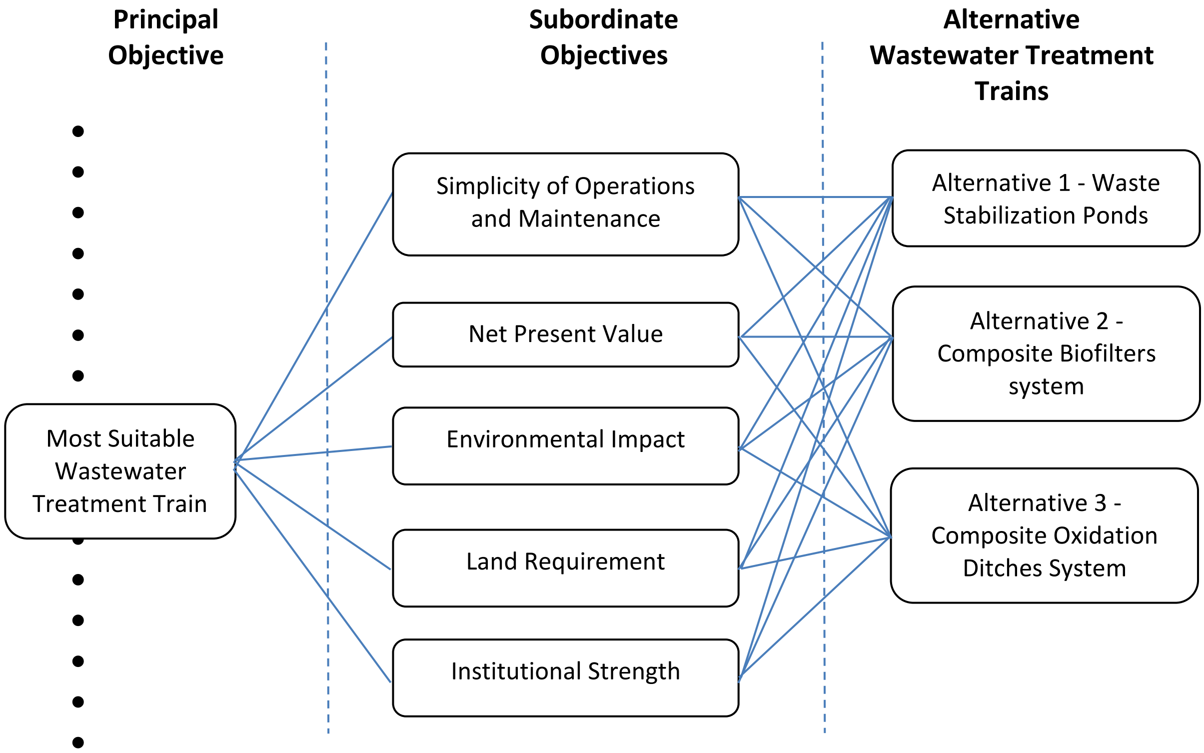


Figure 9.1: Hierarchy Decision Model used in the AHP

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

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 Variable Matrices for all the Parameters with respect to Alternative Treatment Trains are given in **Volume 2: Master Plan Annexes – Chapter 9.**

Table 9.6: Decision Variable Matrix based on Environmental Impact

	Waste Stabilization Ponds	*Composite Biofilters*	*Composite Oxidation Ditches*
Waste Stabilization Ponds	1	2	3
Composite Biofilters	1/2	1	2
Composite Oxidation Ditches	1/3	1/2	1

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

	Waste Stabilization Ponds	*Composite Biofilters*	*Composite Oxidation Ditches*
Waste Stabilization Ponds	1	4	4
Composite Biofilters	1/4	1	1
Composite Oxidation Ditches	1/4	1	1

Table 9.8: Decision Variable Matrix based on Net Present Value

	Waste Stabilization Ponds	*Composite Biofilters*	*Composite Oxidation Ditches*
Waste Stabilization Ponds	1	3	4
Composite Biofilters	1/3	1	2
Composite Oxidation Ditches	1/4	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	0.690	0.600	0.532	0.156	0.656	0.584	1
Composite Biofilters	0.156	0.252	0.303	0.269	0.208	0.253	2
Composite Oxidation Ditches	0.153	0.149	0.165	0.575	0.136	0.162	3

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 the Wastewater Management Scheme for Lamu Island.

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 Lamu Island are briefly described below;

9.3.1.1 Land-Use

In the Land-use Map, different areas of Lamu Island 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 Lamu Island 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

Due to the definite topography of Lamu Island, a single site has been identified within the study area suitable for development of Wastewater Treatment Plant; the site is situated at **Taifu Site**.

The site is located at the intersection of newly constructed KETRACO power lines that supply power to Lamu Island and another line to Matondoni village. It is situated off the coastline approximately 100m from the mangrove swamp and mangrove forest.

Sea waves overtime have deposited sand from the ocean and created artificial sand dunes within the site. It is currently a bare land within isolated coastline vegetation which includes baobab trees and coconut trees. The site is ideal for establishment of Wastewater Stabilization Ponds.

9.3.1 Evaluation of Proposed Site

The above site has 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 Proposed Wastewater Treatment Plant Site

	Land-use	Distance of Discharge Point from the WWTP to the Environment	Topography of Sewered Area	Topography of Site	Geological Conditions	Existing Infrastructure	Potential for Wastewater reuse	Project Affected Persons
Taifu Site	✓	✓	✓	✓	✓	×	✓	✓

Multicriteria Analysis of the proposed site has been incorporated in the analysis of the developed 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 Lamu Island.

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 Lamu Island 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 Parameters are considered in selection of Wastewater Management Scheme.

9.4.3 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** on **Page 9-10**.

Table 9.11: 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 9.12** below.

Table 9.12: 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 9.13** below.

Table 9.13: 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 9.13** on **Page 9-10**, 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.

9.4.4 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.

However, only a single scheme has been formulated for Lamu Island which consisting of a Centralized Sewerage System with minimal pumping and a Waste Stabilization Pond System at an undeveloped site in Taifu area. This Scheme is recommended for Lamu Sanitation Strategy.

10.0 PRELIMINARY DESIGN OF SELECTED STRATEGY

10.1 Introduction

Lamu Island 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 Lamu comprising of a Sewerage System and Wastewater Treatment Plant, to serve for a period of 20 years (2021 – 2040).

The Wastewater Management Scheme formulated for Lamu Island comprising of a Sewerage System including 10Nr Pumping Stations and a centralized Wastewater Treatment Plant at undeveloped land at Taifu has been analysed by the Multi-criteria analysis and found suitable.

The main components of the proposed sanitation system include;

- Sewerage System comprising of Trunk Sewers and a Reticulation Sewerage Network connecting the Study area of Lamu Island to the Wastewater Treatment Plant
- Sewage Pumping Stations at localized low points along the Sewerage Network
- Wastewater 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 Lamu Island which produced aerial images at 15 cm resolution. A Digital Terrain Model (DTM) was developed and contours generated.

A Digital Topographical Map was developed which showed 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 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 Lamu 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 of the Final Design Stage.

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 Lamu Island 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;

$$Q = V \times A$$

Where:

Q	=	Discharge (m^3/s)
A	=	Sectional area of flow (m^2)

Other standard formulae such as for determining peak factors (See ***sub-section 5.1.4****)* 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.

The Sewerage System for Lamu Island has been developed in consideration of the design criteria discussed in the **Section 6.1** and as 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 Babbitt and Harmon Formulas
Minimum Size of Sewer	200mm Diameter
Hydraulic Design Criteria	Manning's Equation with the following design parameters: • Pipe roughness coefficient, n 0.013 • 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
Depth of Sewers	Depths range from 0.4m to 6.0m
Spacing of Manholes	60m maximum spacing between manholes
Pipe Materials	• HDPE/ uPVC Pipes • Socket and Spigot Concrete Pipes • Steel Pipes with internal and external epoxy coating

In summary, 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.

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. <u>Manhole Details</u>

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*).

iv. Proposed Sewer Slope (m/m)

The contours generated within the Study Area from the Digital Terrain Model have been used to generate the profiles of the Sewers.

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 and depth of the pipe.

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 Lamu Island

Sewerage Analysis Model indicates that the range of diameter for the Sewers in Lamu Island is 225 – 450 mm. The large diameter sewer of 450 mm is for the Trunk Sewer while the small diameter of 225 mm is for the secondary sewers.

A Layout Plan of the proposed Sewerage Network for Lamu Island is given in **Figure 10.1** on **Page 10-6**.

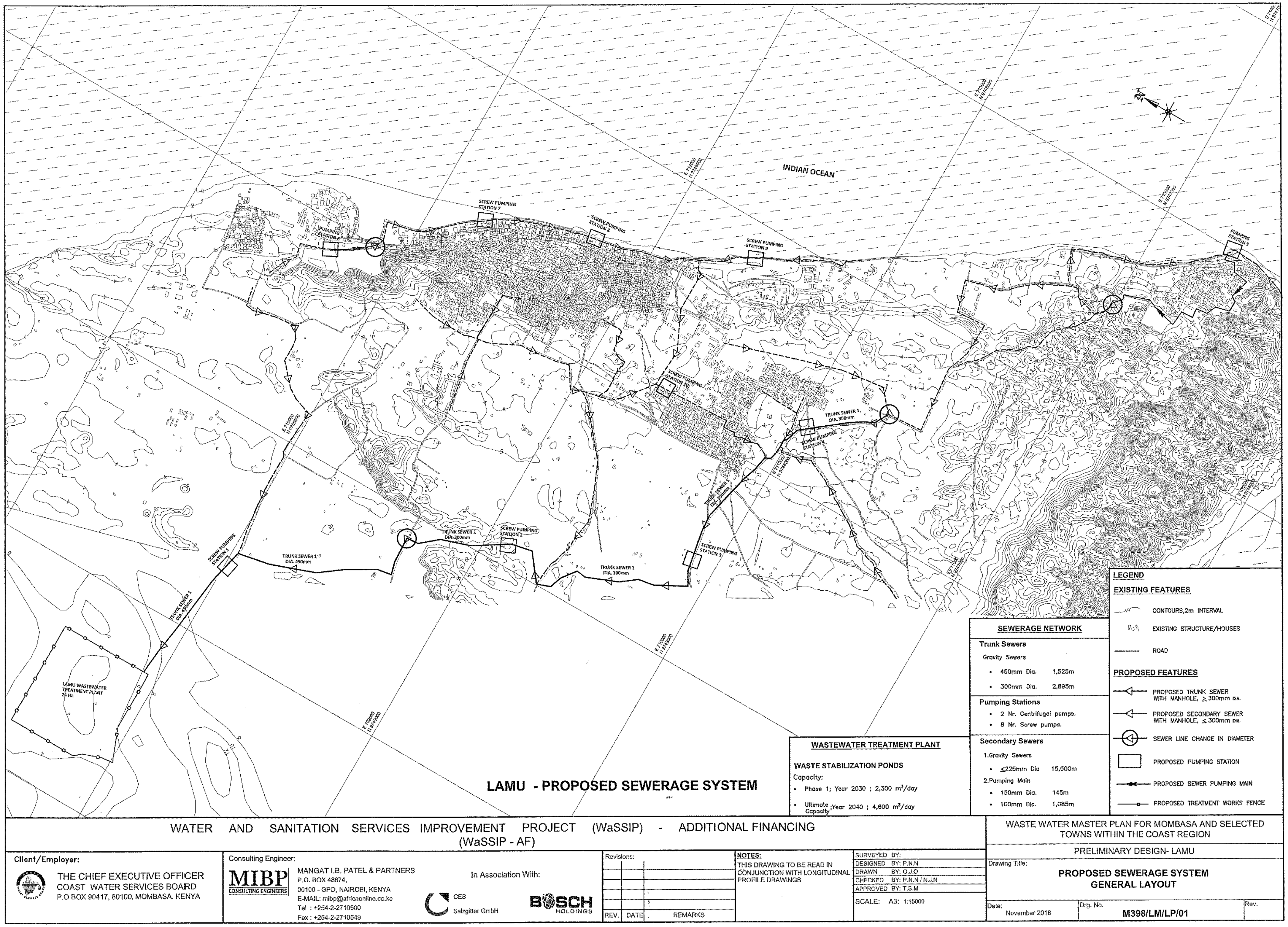


Figure 10.1: Detailed Layout of the Sewerage System

10.2.7 Phased Investment Schedule for Sewerage Network

The Proposed Wastewater Management Strategy for Lamu Island entails construction of new Wastewater 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 Lamu Island i.e., Central Business District
- Population Densities – High Density and Medium Density Residential Zones
- Land-Use Plan – Water Intensive Activities i.e., Industrial Zones

Two implementation phases have been formulated for Lamu Island as 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 Wastewater 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 CBD of Lamu Island or adjacent to the WWTP
- Secondary Sewers serving Industrial Zones and other Water Intensive Land-Use Zones situated near the core CBD of Lamu Island 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	450	2625	Concrete S&S
2	-Ditto-	300	1800	Concrete S&S
3	-Ditto-	100	220	Steel
4	Secondary Sewers - SS	225	8210	HDPE / 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	Pumping Main	100	1,085	Steel
2	Secondary Sewer - SS	225	6,740	HDPE / uPVC

A Layout Plan of the proposed Sewerage Network for Lamu Island showing each of the Sewerage Implementation Phases is given in **Figure 10.2** on **Page 10-8**.

Detailed calculation sheets for the proposed Trunk Sewers based on the Sewerage Network Analysis Model is given in **Volume 2: Master Plan Annexes – Chapter 10**.

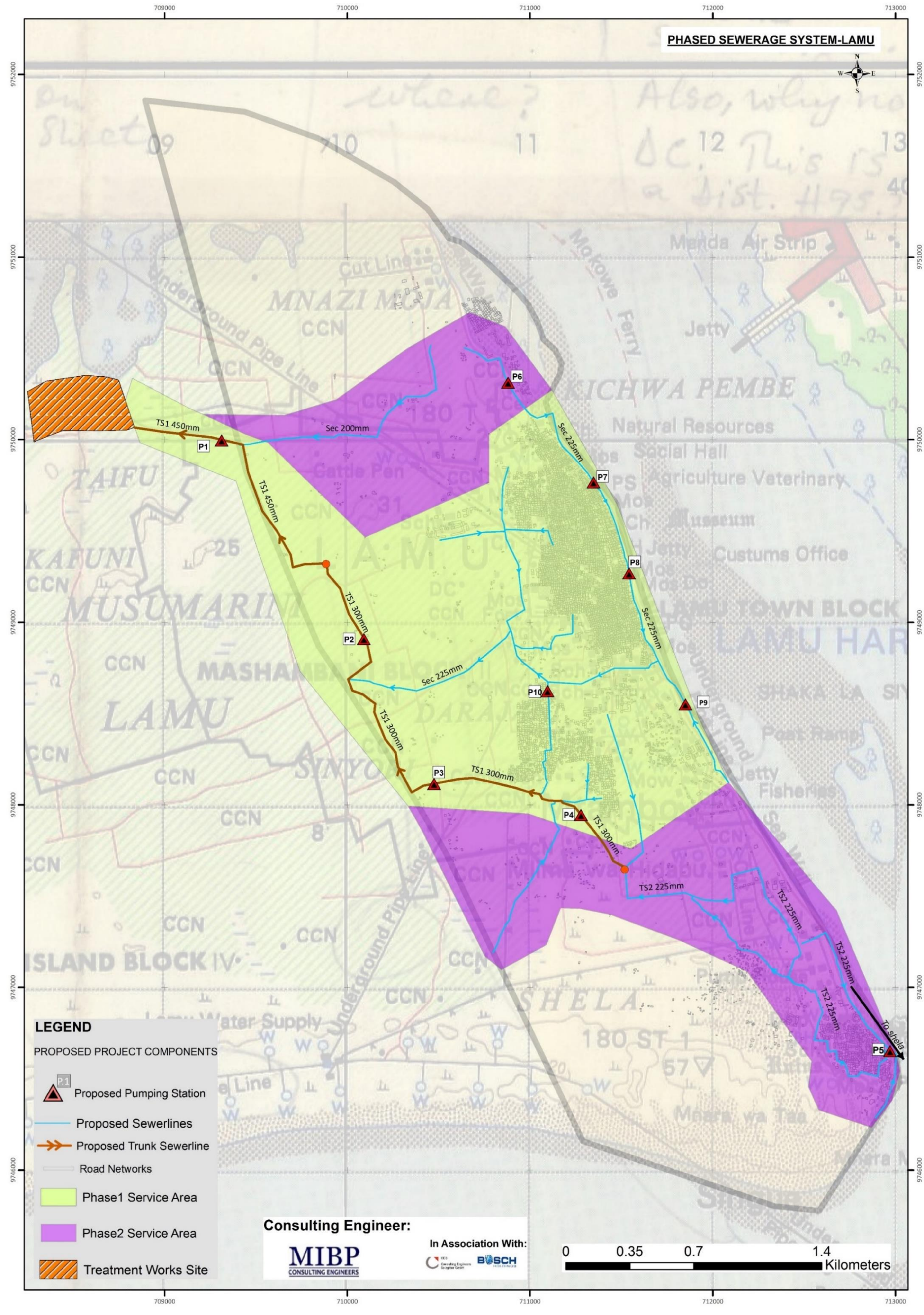


Figure 10.2: Layout Plan of the Phased Implementation of Sewerage System

10.3 Pumping Stations

10.3.1 Siting of Pumping Stations

The pumping stations for the Sewerage System in Lamu Island 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 Lamu, namely;

- Screw Pump Stations (8 Nr), and
- Dry Well Station type (2 Nr) with separate Sewage Sump for temporary storage of conveyed sewage.

Screw Pump Stations have been adopted in circumstance where lifting of sewage is required within heads less than 10 m and where topography of the Sewerage alignment permits construction of such station. 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 Station 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 Lamu Island 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	Pump Details			Implementation Phase	
			Design Flow, Q (m^3/h)	Pumping Head, H (m)	Power Requirement, P (kW)	2021 – 2025	2026 - 2040
P1	Screw	Screw	345	5	6	✓	✓
P2	Screw	Screw	295	7	7	✓	✓
P3	Screw	Screw	261	5	4	✓	✓
P4	Screw	Screw	232	5	4	✓	✓
P5	Dry Well	Vertical Centrifugal	27	45	5	×	✓
P6	Dry Well	Vertical Centrifugal	30	16	2	×	✓
P7	Screw	Screw	18	4	1	✓	✓
P8	Screw	Screw	19	4	1	✓	✓
P9	Screw	Screw	17	4	1	✓	✓
P10	Screw	Screw	30	5	1	✓	✓

Figures 10.3 and **10.4** on **Pages 10-11** and **10-12** 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 10-8** shows the location Plan 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 – Chapter 10.**

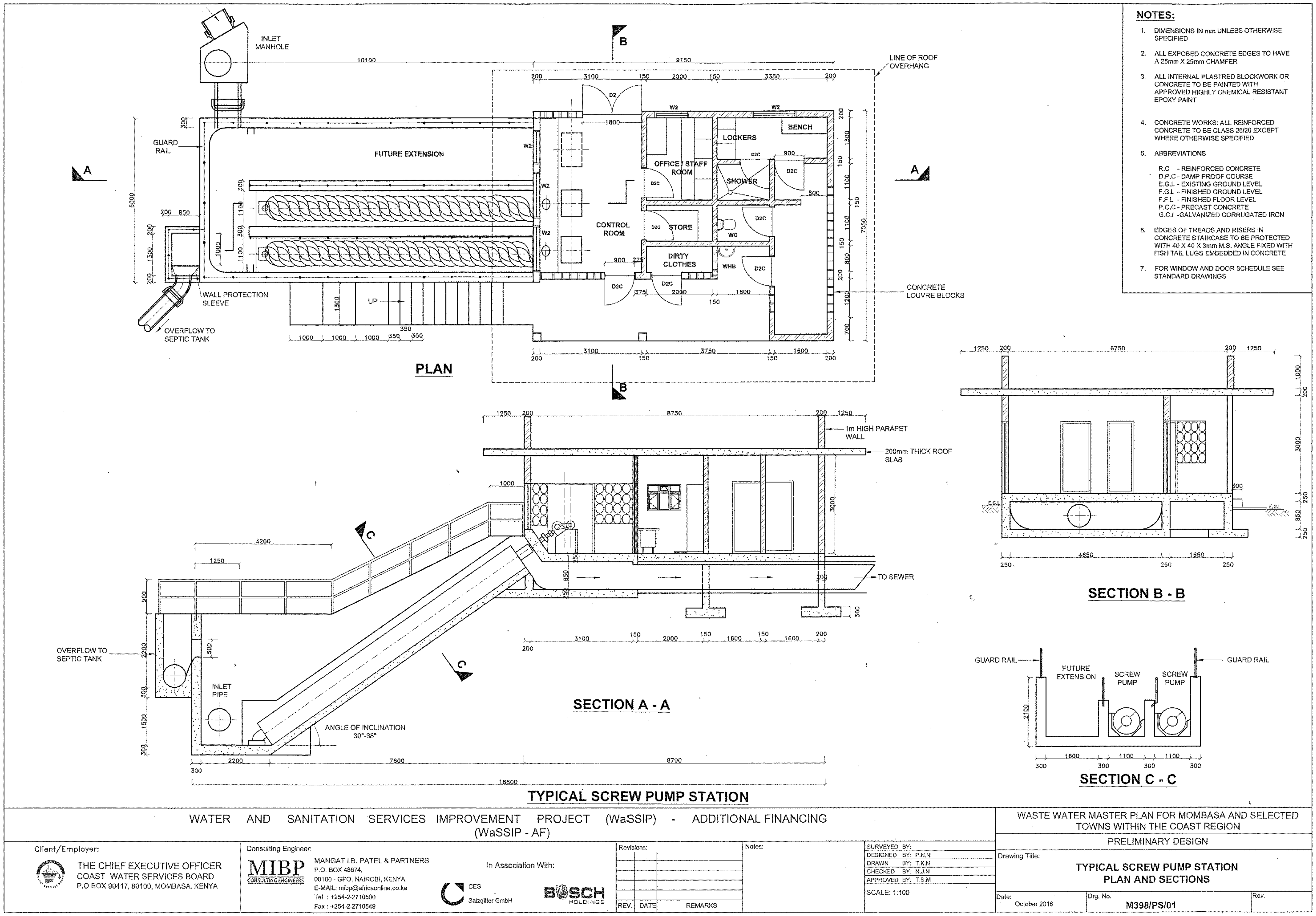


Figure 10.3: Layout Plan and Sections of a Screw Pumping Station

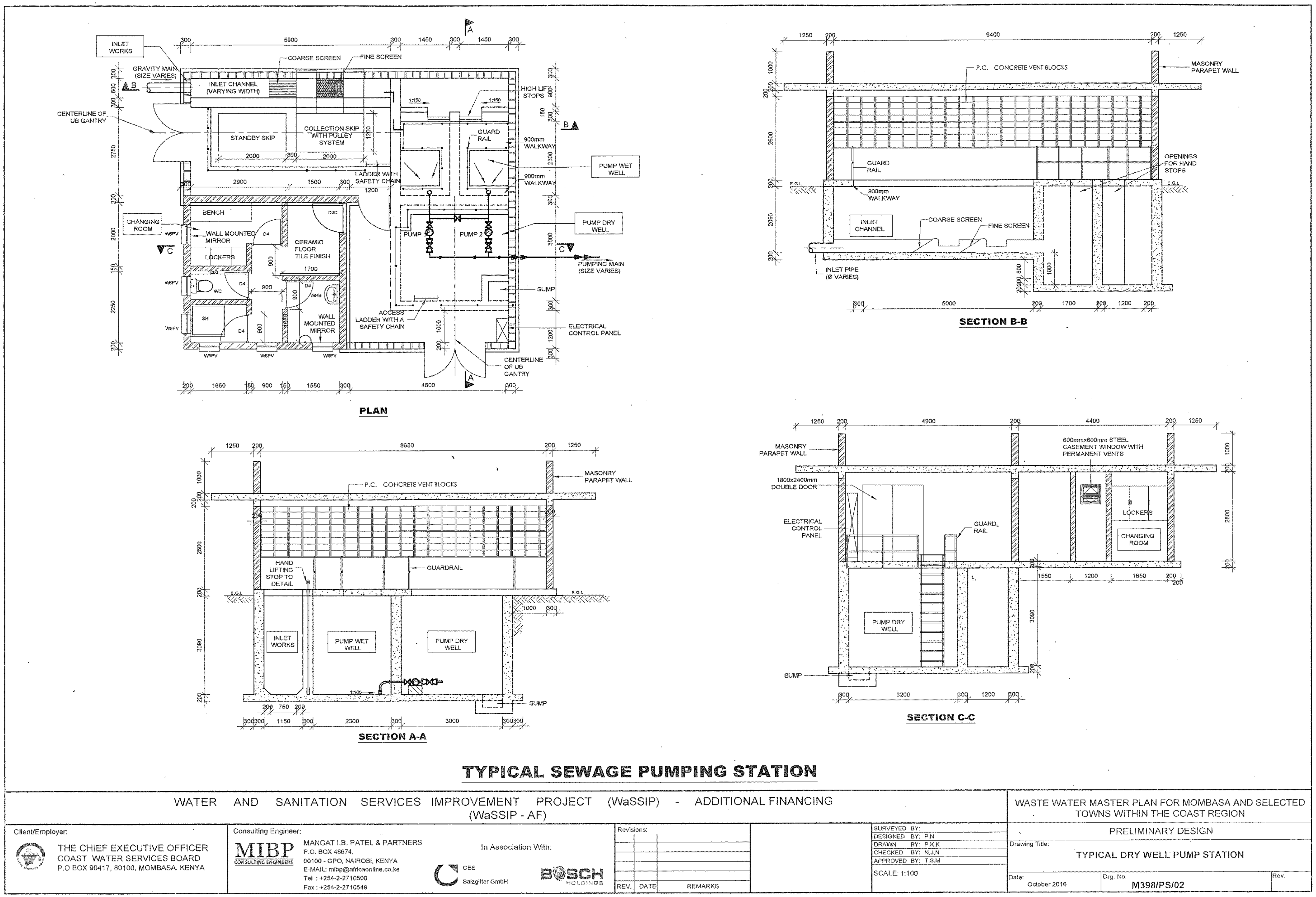


Figure 10.4: Layout Plan and Sections of a Centrifugal Pumping Station

10.4 Wastewater Treatment Plants

10.4.1 Treatment Technology Selection

A summary of the comparison of the various locally available treatment technologies have 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 loads - 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 simple and so the cost of construction is generally lower than for plants for other treatment technologies. 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.

Besides, the high, year-round, ambient temperatures, availability of un-developed land within Lamu Island as well as the simplicity of construction, render WSPs the most preferred wastewater treatment technology.

10.4.2 Treatment Plant Location

A centralized Wastewater Treatment Plant is proposed in an un-developed land in Taifu area (708701 m E, 9750199 m S). The location of the Wastewater Treatment Plant is shown on **Figures 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 Lamu Island can be conveyed by minimal pumping to the site, land availability 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 – 4,600 m³/d*; *Refer to Subsection 5.2*), the land required for the construction of the Wastewater Treatment Plant to serve the sanitation needs of Lamu Island up to the ultimate horizon of year 2040, is approximately **15 Ha.**

The proposed site on the un-developed land is privately owned and acquisition is necessary. It lies close to the creeks of Lamu on the shores of Indian Ocean and the effluent can be discharged directly to the creek through a relatively short outfall sewer.

The site slopes towards the ocean with sufficient slope to permit an adequate hydraulic profile through the ponds without incurring excessive earthworks.

The site is close to services such as water and electricity. However, construction of a well-surfaced access road is necessary.

10.4.3 Design Considerations

Many different methods have been proposed for the design of Waste Stabilisation 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 Lamu Island 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/m^{3}d and 300 g/m^{3}d. 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(^{o}C)	Volumetric Loading, λv (g/m^{3}d)
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 Lamu Town are consistently moderately high throughout the year and a mean temperature in the coldest month of 25.6°C has been adopted. This mean temperature results to an allowable organic surface loading of 362 kg BOD/ha/day.

The depth of facultative ponds is based upon a compromise of 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:

$$N_e = N_i/(1+k_T\theta)$$

Where,
N_e = number of FC/100ml in the effluent
N_i = number of FC/100ml in the influent
k_T = first order rate constant for FC removal, d^{-1}
θ = retention time, days

The rate constant is highly temperature dependent and for a temperature of 25.6 °C it has a value of 6.89 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 $5x10^7$ 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 maturations 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	$5x10^7$
Design Temperature	°C	25.6
First Order Rate Constant for FC Removal	day^{-1}	6.89
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
Primary Facultative Ponds:		
Organic Surface Loading, λs	kg/ha/day	362
Depth of Facultative Ponds	m	1.5
Retention time in Primary Facultative Pond	Days	≈ 10
Maturation Ponds:		
Depth of Maturation Ponds	m	1.5
Retention in each Maturation Pond	Days	≈ 3

10.4.4 Wastewater Treatment Plant Details

Waste Stabilization Pond system has been designed to serve the sanitation needs of Lamu Island up to the ultimate design horizon of Year 2040.

Table 10.7 below shows a summary of details of the Wastewater Treatment Plant designed to serve the sanitation needs of up to Year 2040.

Table 10.7: Details of Wastewater Treatment Plant – Year 2040

Design Parameter	Unit	Value
Anaerobic Ponds:		
Number of Ponds	No.	4
Retention Period (Each Pond)	Days	2
Dimensions (Embankment)	m	47 (L) x 28 (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	7
Dimensions (Embankment)	m	138 (L) x 46 (B) x 1.5 (D)
Secondary Facultative Ponds:		
Number of Ponds	No.	4
Retention Period (Each Pond)	Days	2
Dimensions (Embankment)	m	45 (L) x 42 (B) x 1.5 (D)
Maturation Ponds:		
Number of Ponds	No.	8
Retention Period (Each Pond)	Days	2
Dimensions	m	43 (L) x 42 (B) x 1.5 (D)
Sludge Drying Beds:		
Number of Beds	No.	4
Dimensions (Embankment)	m	40 (L) x 20 (B) x 1.5 (D)

The Site Layout Plan of the proposed Wastewater Treatment Plant is given in **Figure 10.5** on **Page 10-17**.

Typical details on the Inlet and Outlet Structures are also given in **Figure 10.6** on **Page 10-18.**

Detailed calculation sheets of the Wastewater Treatment Plants (Year 2030 and Year 2040) is given in **Volume 2: Master Plan Annexes – Chapter 10.**

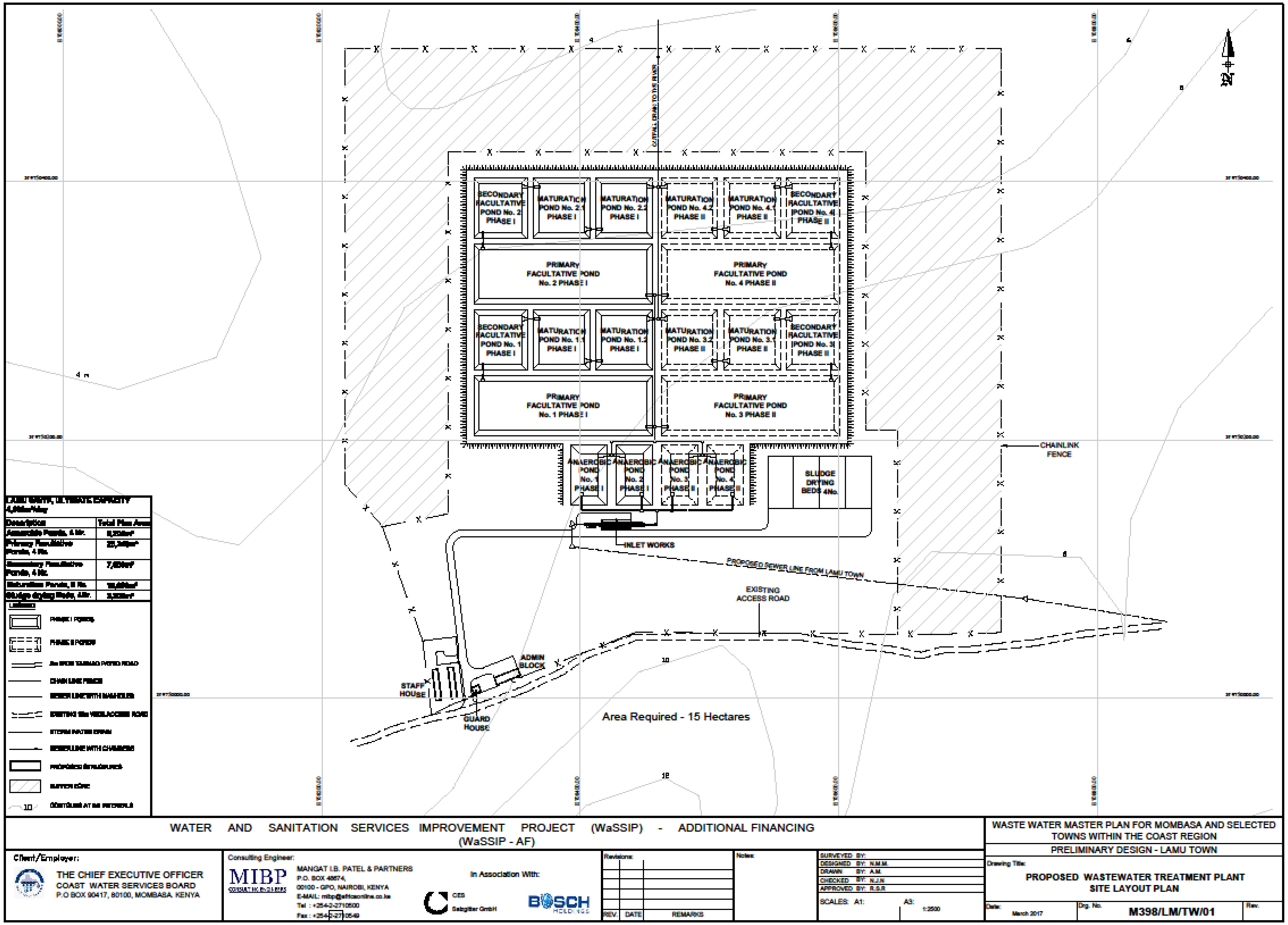


Figure 10.5: Site Layout Plan of the Proposed Wastewater Treatment Plant

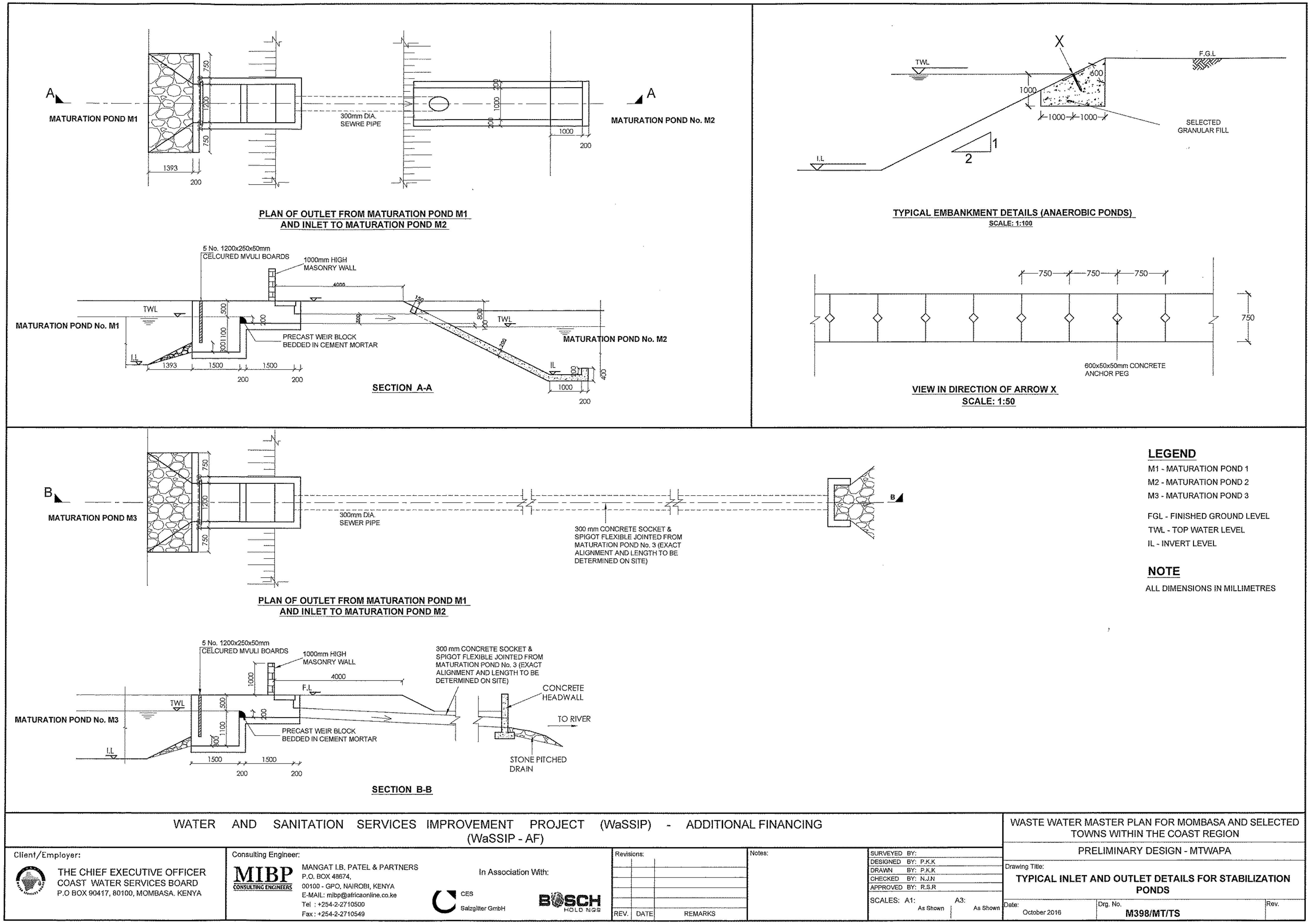


Figure 10.6: Typical Inlet and Outlet Structures for the Ponds

10.4.5 Phased Investment Schedule for Wastewater 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 Wastewater 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 Wastewater Treatment Plant to serve the sanitation needs of Lamu Island up to year 2025. To provide for an additional capacity during the implementation of the second phase (Long-Term Plan; 2025 - 2040), the treatment plant has been designed to accommodate the wastewater generated up to year 2030.

From **Figure 5.1** on **Page 5-5,** the projected wastewater flow for year 2030 is approximately 2,300 m^3/d, based on realistic conditions of water supply and sewer connections. However, the WWTP has been designed for half the ultimate capacity i.e. 4,600 m^3/d for ease of phasing of multiple and identical sets of ponds.

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 Wastewater 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	47 (L) x 28 (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	7
Dimensions (Embankment)	m	138 (L) x 46 (B) x 1.5 (D)
Secondary Facultative Ponds:		
Number of Ponds	No.	2
Retention Period (Each Pond)	Days	2
Dimensions (Embankment)	m	45 (L) x 42 (B) x 1.5 (D)
Maturation Ponds:		
Number of Ponds	No.	4
Retention Period (Each Pond)	Days	2
Dimensions	m	43 (L) x 42 (B) x 1.5 (D)
Sludge Drying Beds:		
Number of Beds	No.	2
Dimensions (Embankment)	m	40 (L) x 20 (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 Wastewater Treatment Plant to handle the increased ultimate wastewater generation of year 2040 i.e. 4,600 m^3/d, based on realistic conditions of water supply and sewer connections.

Construction of these additional units should commence by year 2028 to ensure their operation by year 2030.

Details of the Wastewater Treatment Units required for Long-Term Plan is given in **Table 10.7** on **Page 10-16.**

The details of the second Implementation Phase which is meant to provide the additional capacity of 2,300 m³/d at the Wastewater Treatment Plant is given in **Table 10.9** below;

Table 10.9: Details of Additional Units at the Wastewater 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	47 (L) x 28 (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	7
Dimensions (Embankment)	m	138 (L) x 46 (B) x 1.5 (D)
Secondary Facultative Ponds:		
Number of Ponds	No.	2
Retention Period (Each Pond)	Days	2
Dimensions (Embankment)	m	45 (L) x 42 (B) x 1.5 (D)
Maturation Ponds:		
Number of Ponds	No.	4
Retention Period (Each Pond)	Days	2
Dimensions	m	43 (L) x 42 (B) x 1.5 (D)
Sludge Drying Beds:		
Number of Beds	No.	2
Dimensions (Embankment)	m	40 (L) x 20 (B) x 1.5 (D)

10.5 Phased Investment Costs

10.5.1 Land Acquisition Cost

Approximately 15 Ha of land is required for the construction of Wastewater Treatment Plant and Pumping Stations in Lamu Island 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. 75,000,000.**

The requisite parcel of land need to be acquired in the Medium-Term Plan.

10.5.2 Implementation Costs for Phased Sewerage System

The estimated cost for each of the Implementation Phases for the Sewerage System 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)	Cost (USD)
1	Trunk Sewers	67,575,224	656,070
2	Secondary Sewers	94,975,100	922,088
3	Pumping Mains	2,190,104	21,263
4	Pumping Stations	29,700,000	288,350
	Sub-Total 1	**194,440,428**	**1,887,771**
	Add 7.5% of Sub-Total 1 for Preliminary and General	14,583,032	141,583
	Sub-Total 2	**209,023,460**	**2,029,354**
	Add 10% of Sub-Total 2 for Physical Contingencies	20,902,346	202,935
	Sub-Total 3	**229,925,806**	**2,232,289**
	Add 10% of Sub-Total 3 for Price Contingencies	22,992,581	223,229
	Sub-Total 4	**252,918,387**	**2,455,518**
	Add 5% of Sub-Total 4 for Consultancy	12,645,919	122,776
	GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**265,564,306**	**2,578,294**

Table 10.11: Costs Phase 2 Sewerage System: Long-Term Plan

S/No	Item Description	Cost (Kshs)	Cost (USD)
1	Secondary Sewers	96,223,914	934,213
2	Pumping Mains	15,732,500	152,743
3	Pumping Stations	8,100,000	78,641
	Sub-Total 1	**120,056,414**	**1,165,596**
	Add 7.5% of Sub-Total 1 for Preliminary and General	9,004,231	87,420
	Sub-Total 2	**129,060,645**	**1,253,016**
	Add 10% of Sub-Total 2 for Physical Contingencies	12,906,064	125,302
	Sub-Total 3	**141,966,709**	**1,378,318**
	Add 10% of Sub-Total 3 for Price Contingencies	14,196,671	137,832
	Sub-Total 4	**156,163,380**	**1,516,149**
	Add 5% of Sub-Total 4 for Consultancy	7,808,169	75,807
	GRAND TOTAL INCLUDING PRELIMI AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**163,971,549**	**1,591,957**

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 Lamu 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)	Cost (USD)
1	Inlet Works	1	10,287,205	99,876
2	Anaerobic Ponds	2	49,325,648	478,890
3	Primary Facultative Ponds	2	47,352,622	459,734
4	Secondary Facultative Ponds	2	12,824,669	124,511
5	Maturation Ponds	4	25,649,337	249,023
6	Sludge Drying Beds	2	17,757,233	172,400
7	Administration Building	1	8,850,000	85,922
8	Staff Houses	2	4,500,000	43,689
9	Site and Ancillary Works	-	20,966,928	203,562
		Sub-Total 1	**197,513,642**	**1,917,608**
		Add 7.5% of Sub-Total 1 for Preliminary and General	14,813,523	143,821
		Sub-Total 2	**212,327,165**	**2,061,429**
		Add 10% of Sub-Total 2 for Physical Contingencies	21,232,716	206,143
		Sub-Total 3	**233,559,881**	**2,267,572**
		Add 10% of Sub-Total 3 for Price Contingencies	23,355,988	226,757
		Sub-Total 4	**256,915,870**	**2,494,329**
		Add 5% of Sub-Total 4 for Consultancy	12,845,793	124,716
		GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**269,761,663**	**2,619,045**

Table 10.13: Costs for Phase 2 Wastewater Treatment Plant: Long-Term Plan

S/No.	Components	No.	Cost (Kshs)	Cost (USD)
1	Anaerobic Ponds	2	49,325,648	478,890
2	Primary Facultative Ponds	2	47,352,622	459,734
3	Secondary Facultative Ponds	2	12,824,669	124,511
4	Maturation Ponds	4	25,649,337	249,023
5	Sludge Drying Beds	1	17,757,233	172,400
6	Site and Ancillary Works	-	4,065,480	39,471
		Sub-Total 1	**156,974,989**	**1,524,029**
		Add 7.5% of Sub-Total 1 for Preliminary and General	11,773,124	114,302
		Sub-Total 2	**168,748,113**	**1,638,331**
		Add 10% of Sub-Total 2 for Physical Contingencies	16,874,811	163,833
		Sub-Total 3	**185,622,925**	**1,802,164**
		Add 10% of Sub-Total 3 for Price Contingencies	18,562,292	180,216
		Sub-Total 4	**204,185,217**	**1,982,381**
		Add 5% of Sub-Total 4 for Consultancy	10,209,261	99,119
		GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**214,394,478**	**2,081,500**

Exchange Rate: 1 USD = 103 Kshs

10.5.4 Summary of Phased Investment Costs

A summary of the Phased Investment cost for Lamu Island Wastewater Management System 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	75,000,000	728,155
2	Sewerage System	265,564,306	2,578,294
3	Wastewater Treatment Plant	269,761,663	2,619,045
	Total	**610,325,969**	**5,925,494**

Table 10.15: Costs for Long-Term Plan (Year 2026 – 2040)

S/No.	Component	Cost (Kshs)	Costs (USD)
1	Sewerage System	163,971,549	1,591,957
2	Wastewater Treatment Plant	214,394,478	2,081,500
	Total	**378,366,027**	**3,673,457**

10.6 Wastewater Reuse

10.6.1 Justification for Wastewater Reuse

The Proposed Wastewater Treatment Plant (WWTP) for Lamu Island comprising of Waste Stabilization Ponds System (ultimate design capacity of 4,600 m^3/day) is to be sited in an undeveloped land in Taifu 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 Lamu, 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 Lamu Island.

10.6.2 Types of Wastewater Reuse Applications

The main wastewater reuse applications are described in the sub-sequent sections;

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 Lamu 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 Lamu, 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 Lamu Island.

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.

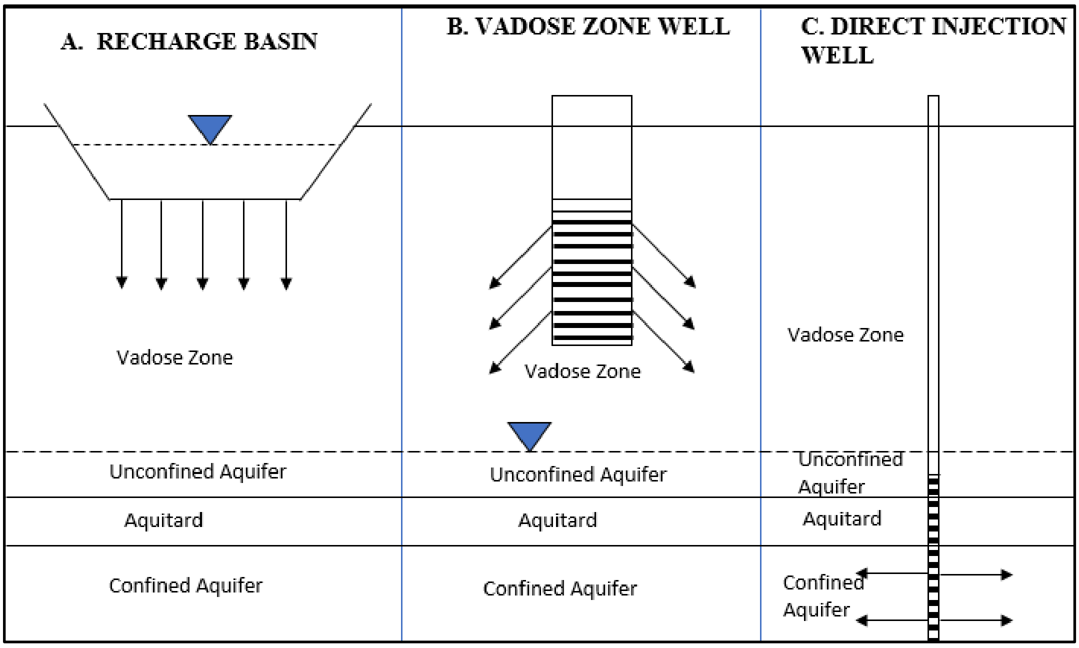


Figure 10.7: Types of Aquifer Recharge

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 Lamu 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 water 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 10-26.**

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 Lamu 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 / Storage Pond for water reuse)

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 Lamu Island is given in **Figure 3.4** 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 Lamu, i.e., Agricultural, Industrial and Environmental

Details of proposed area allocated for Agricultural, Industrial and Environmental land uses in the year 2040 for Lamu 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	63
2.	Industrial	1.3
3.	Environmental	136
4	Undeveloped	597

Based on **Table 10.17** above, the following conclusion can be drawn:

- Agricultural activities are less dominant in Lamu compared to fishing and tourism. Besides, the proposed area for Agricultural Land Uses is relatively small and located far from the WWTP site. However, the undeveloped land is significant and with availability of water from reuse scheme, and it has been assumed the change of land-use from undeveloped to agricultural land will be necessitated and implemented.
- There are insignificant parcels of land allocated for Industrial Land Uses within the Area of Interest (AoI), thus wastewater reuse for industrial purposes will not be applicable in Lamu.
- The recreational areas within Lamu Island are and would make conveyance of wastewater for reuse expensive.

In conclusion, agriculture application after inclusion of land designated as undeveloped land is the most suitable for wastewater reuse considering the level of wastewater treatment at the Wastewater Stabilization Ponds and the predominant undeveloped land available in Lamu.

Surface irrigation of orchards is the most preferred wastewater reuse application in Lamu. The volumetric water requirement for the agricultural wastewater reuse is determined by the fruit tree cultivated among other factors.

A schedule of fruit trees cultivated in Lamu and their water requirements is given in **Table 10.18** below.

Table 10.18: Water requirements for Cash Crops cultivated

	Cash Crop	Water requirement (m^3/ha/day)
1.	Mango Trees	55
2.	Coconuts	360
3.	Cashew nuts	1545
4.	Citrus	35
7.	Copra	80
8.	Macadamia nuts.	20

It has been established during the visits and investigations of the Study Area that Mango is the predominant Fruit Tree cultivated in the area.

The establish the potential irrigable land in Lamu, the following assumptions have been made;

a. The fruit tree to be cultivated on the irrigated land is mango; with water requirement of 55 m^3/ha/day
b. Only 80% of the treated wastewater will be available for reuse in consideration of the losses due to evaporation, seepage and transmission losses
c. 40% of the stakeholders within the area proposed for surface irrigation of orchards 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 4,600 m^3/day

= 3,680 m^3/day

The gross total area which can be put under irrigation considering only the 40% utilization is given by;

Gross Total Area, $A_G = \frac{3{,}680\ m3/d}{55\ m3/ha/d\ x\ 0.4}$

= **167 Ha**

Therefore, the available wastewater for agricultural reuse application is adequate for farms with total coverage of approximately **170 ha**.

A layout plan showing the proposed land which can be irrigated with wastewater reuse (170 Ha) is shown in **Figure 10.9** on **Page 10-29.**

10.6.5 Conveyance and Storage System of wastewater for Reuse

To cover the potential irrigable area of **170 Ha**, the treated water will be conveyed from the WWTP site at an elevation of 6 m asl to a Storage Facility at an elevation of 8 m asl by means of pumping. The distance between these points is approximately 1.6 km.

The Conveyance and Storage system shall comprise of the following components;

a) Pumping Station at the WWTP
- Pump Discharge – 383 m^3/hr
- Pumping Head - 22 m
- Power requirement - 32 kW.

b) Rising Main
- Pipe Material - Steel pipe
- Diameter - 300 mm
- Length – 1.6 Km.

c) Lined Pond for storage
- 1.5-m deep well compacted Earth Pond (Capacity 3,500 m^3)
- Proposed site; co-ordinates 709259 m E, 9750247 m S
- Land requirement – **0.6 ha**

d) Overflow Sewer & Manholes
- To connect Lined Pond to Lamu Creeks.
- Pipe Details - 300-mm diameter concrete pipe
- Length - approximately 0.5 Km

A layout plan showing the Conveyance and Storage system is shown on **Figure 10.9** on **Page 10-29.**

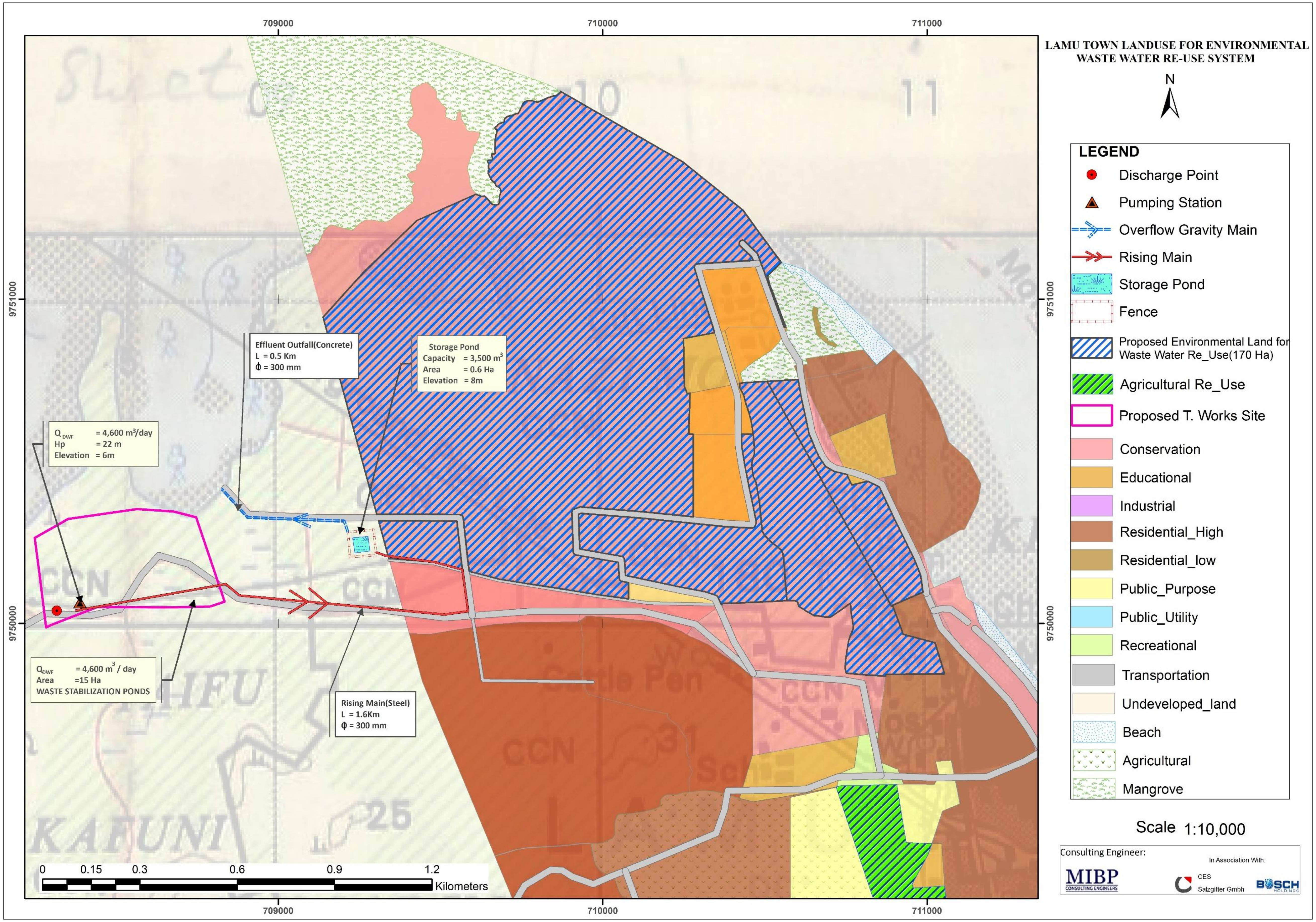


Figure 10.9: Layout Plan of the Conveyance and Storage System for Agricultural Wastewater Reuse – Lamu

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 Lamu 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%

A summary of the Capital Costs for the Wastewater Reuse Scheme is given in **Table 10.19** below.

Table 10.19: Capital Cost for Agricultural Wastewater Reuse Scheme – Lamu

S/No.	Component	Cost, Kshs	Cost, USD
1	**Land Acquisition**	**4,116,667**	**39,967**
2	**Civil Works**	106,251,639	1,031,569
2.1	Pumping Station	6,070,604	58,938
2.2	Rising Main	47,914,485	465,189
2.3	Overflow Sewer & Manholes	12,966,549	125,889
2.4	Storage Pond	39,300,000	381,553
3	**Electro-Mechanical Works**	**4,047,070**	**39,292**
3.1	Pumping Stations	4,047,070	39,292
	Total Capital Cost	**114,415,375**	**1,110,829**

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 with increase sewer connections (same rate as population growth rate)
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** below.

Table 10.20: Annual Operations & Maintenance Costs

S/No.	Component	Cost, Kshs	Cost, USD [1]
1	Maintenance Costs	1,363,694	13,240
2	Electricity Costs	1,050,701	10,201
3	Staff Costs	960,000	9,320
	Total O & M Cost	**3,374,395**	**32,761**

[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 Lamu is **Kshs. 160,533,755**.

10.6.6.4 Additional Cost for Wastewater Reuse Scheme

Treated wastewater for reuse in Lamu will be conveyed for reuse without any advanced tertiary treatment.

However, additional costs are to be incurred in the storage and conveyance systems.

This additional cost has been determined as follows;

- NPV of the Scheme for 20-year period = Ksh. 160,533,755
- Gross volume of reuse water pumped from the WWTP per day = 4,600 m^3/d
- Gross volume of reuse wastewater conveyed during 20-year period = 33,580,000 m^3
- Unit additional cost incurred during 20-year period $= \frac{160{,}533{,}755}{33{,}580{,}000}$

  = Ksh 4.78 per m^3

Based on the information above, the additional Cost of Conveying and Storing wastewater for agricultural reuse in Lamu is; Ksh 4.78 per m^3.

10.6.6.5 Conclusion

The following conclusions are derived from the assessment of Wastewater Reuse in Lamu;

a) Agriculture is the most suitable wastewater reuse applications in Lamu especially on Surface Irrigation of orchards.
b) Additional cost for conveyance and storage of the 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 Lamu is approximately **Ksh. 4.78 per m^3**
   ii. Unit cost of abstracting, treating and conveying potable water is Ksh. **13.62 per m^3** (Feasibility Study for Kapsoya Treatment Work – 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
      - Cost of irrigation systems and conveyance to the reuse sites
   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, LAWASCO, organized community groups and private sector for the success of the Agricultural Wastewater Reuse System.

11.0 FINANCIAL ANALYSIS FOR THE SELECTED DEVELOPMENT STRATEGY

11.1 Background

This chapter provides results for financial, economic and social analysis for the investments associated with the Lamu Wastewater Management Scheme, hereafter referred to as the Project. 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

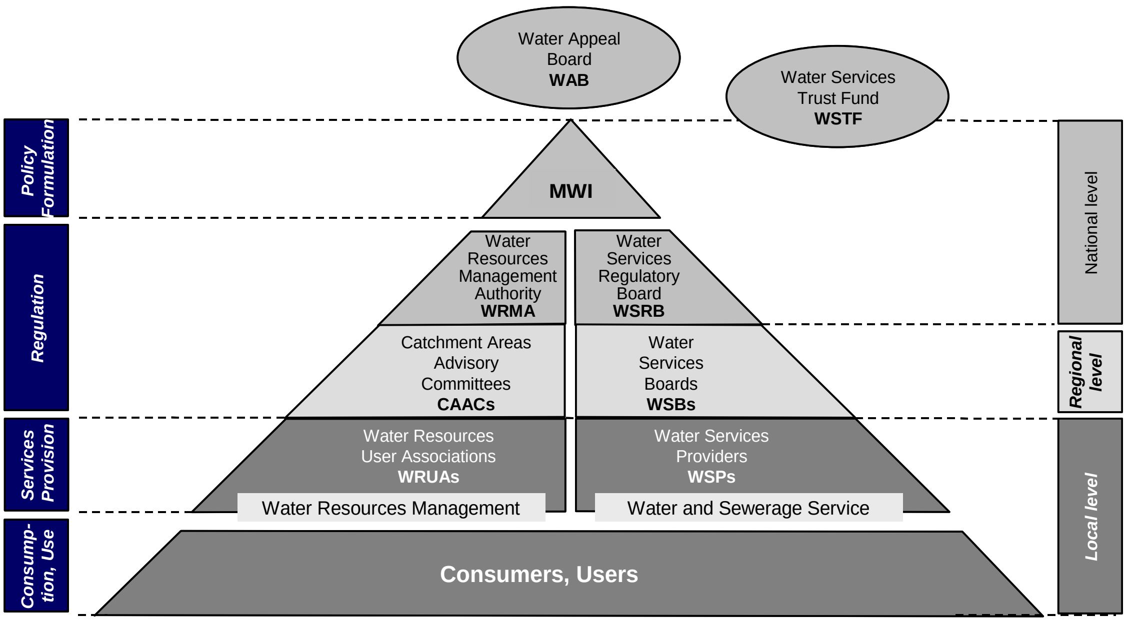
Prior to 2002, the performance of the water and sanitation sector in Kenya faced various challenges. Some of the key challenges include;

- 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 and water services provision; separated 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:



* Details in new institutions flyer
Source: WSRS

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 or supply 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; and
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 5.3 m^3 to 25 m^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 Lamu Water and Sewerage Company Limited (LAWASCO)

The Lamu Water & Sewerage Company Ltd. (LAWASCO Ltd.) was established in 2003 as a limited liability company. At present, the company is owned by the Lamu County Government.

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 exhaust 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 has proposed a tariff adjustment in 2017 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.

The 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 – LAWASCO

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	55	0-6	75.00	56.25	86.67	65.00
7-20	75	7-20	85.00	63.75	130.00	97.50
21-50	97.5	21-50	105.00	78.75	169.00	126.75
51-100	120	51-100	140.00	105.00	208.00	156.00
101-300	165	101-300	180.00	135.00	260.00	195.00
>300	220	>300	225.00	168.75	225.00	168.75
Commercial/Industrial/Government Institutions						
0-6	55	0-50	95.00	71.25	109.25	81.94
7-20	75					
21-50	97.5					
51-100	120	51-100	120.00	90.00	138.00	103.50
101-300	165	101-200	165.00	123.75	189.75	142.31
>300	220	>200	225.00	168.75	258.75	194.06
Public Boarding Schools/Universities and Colleges						
0-600	40	0-600	50.00	37.50	57.50	43.13
600-1200	50	600-1200	75.00	56.25	86.25	64.69
>1200	90	>1200	100.00	75.00	115.00	86.25
Community Water Supply	*35*		50.00	37.50	57.50	43.13
Water Kiosks	*35*		35.00	26.25	40.25	30.19

Table 11.2: Other charges

Service	Charge in Ksh
Connection fee ½ to 1 inch	2500
Connection fee 1.5 inch to 3 inches	7500
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	15000 and double deposit
Tanker – 8000 litres	2500 per tanker supplied within the LAWASCO Area of Jurisdiction
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 Lamu 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 - 4,600 m^3/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), Ksh	Long-term (2026 – 2040), Ksh	Total, Ksh
Land	75,000,000	-	75,000,000
Sewerage System	265,564,306	163,971,549	429,535,855
Wastewater Treatment Plant	269,761,663	214,394,478	484,156,142
Total	**610,325,969**	**378,366,028**	**988,691,997**

The above costs include Physical and Price Escalation Contingencies, Taxes and Duties and Preliminary and General Items and Consultants Fees. The total investment for the project is **Kshs. 988,691,997**.

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, Ksh	O&M, Ksh	Depreciation, Ksh	Total Cost, Ksh
2021	152,581,492			152,581,492
2022	152,581,492			152,581,492
2023	152,581,492	17,433,327.35	17,751,133.10	187,765,953
2024	152,581,492	17,462,024.48	23,668,177.47	193,711,694
2025	-	17,494,856.87	23,668,177.47	41,163,034
2026	37,836,603	17,527,573.09	25,008,489.39	80,372,665
2027	37,836,603	17,561,663.39	26,475,776.51	81,874,043
2028	37,836,603	17,597,185.49	27,943,063.62	83,376,852
2029	-	17,634,199.52	27,943,063.62	45,577,263
2030	56,754,904	17,672,768.13	30,143,994.29	104,571,667
2031	75,673,206	17,712,956.63	30,275,225.77	123,661,388
2032	94,591,507	17,754,833.04	31,140,100.81	143,486,441
2033	37,836,603	17,798,468.27	29,804,045.17	85,439,116
2034	-	17,843,936.17	27,000,702.43	44,844,639
2035	-	17,891,313.72	27,000,702.43	44,892,016
2040	-	18,159,774.38	23,999,445.35	42,159,220
2045		18,159,774.38	20,176,050.37	38,335,825
2046		18,159,774.38	20,176,050.37	38,335,825

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 (See **Volume 2: Master Plan Annexes – Chapter 11.**);
- Cost of capital (discount factor) 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 varying between 3.8% to 4.3% within the study horizon
- Average of 6 members per household
- About 60% of health expenditure in Lamu Island 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 23,425,000 m^3
- Tourists and Visitors to Lamu Island 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 years. 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 Lamu Wastewater Management Scheme the following activities were undertaken:

(i) identifying and quantifying the Project costs and running costs
(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, Ksh	Collection Efficiency	Average Revenue, Ksh
2023	42,038,851.72	90%	37,834,967
2024	42,038,851.72	90%	37,834,967
2025	51,640,381.22	90%	46,476,343
2025	51,640,381.22	90%	46,476,343
2026	74,776,648.30	90%	67,298,983
2027	74,776,648.30	90%	67,298,983
2028	74,776,648.30	90%	67,298,983
2029	131,861,713.51	90%	118,675,542
2030	131,861,713.51	90%	118,675,542
2031	131,861,713.51	90%	118,675,542
2032	131,861,713.51	90%	118,675,542
2033	131,861,713.51	90%	118,675,542
2034	131,861,713.51	90%	118,675,542
2035	131,861,713.51	90%	118,675,542
2036	131,861,713.51	90%	118,675,542
2037	131,861,713.51	90%	118,675,542
2038	131,861,713.51	90%	118,675,542
2039	248,647,971.73	90%	223,783,175
2040	248,647,971.73	90%	223,783,175
2041	248,647,971.73	90%	223,783,175
2042	248,647,971.73	90%	223,783,175
2043	248,647,971.73	90%	223,783,175
2044	248,647,971.73	90%	223,783,175
2045	248,647,971.73	90%	223,783,175
2046	248,647,971.73	90%	223,783,175

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 (Ksh)							
Year	Total Project Revenue	Billings Not Recovered	Net Project Revenue	Operations & Maintenance	Annual Depreciation	Total Expenditure	Net Revenue
2023	42,038,852	4,203,885	37,834,967	17,433,327	17,751,133	35,184,473	2,650,493
2024	42,038,852	4,203,885	37,834,967	17,462,024	23,668,177	41,130,215	-3,295,249
2025	51,640,381	5,164,038	46,476,343	17,494,857	23,668,177	41,163,048	5,313,295
2026	74,776,648	7,477,665	67,298,983	17,527,573	25,008,489	42,536,076	24,762,907
2027	74,776,648	7,477,665	67,298,983	17,561,663	26,475,777	44,037,454	23,261,529
2028	74,776,648	7,477,665	67,298,983	17,597,185	27,943,064	45,540,264	21,758,720
2029	74,776,648	7,477,665	67,298,983	17,634,200	27,943,064	45,577,278	21,721,705
2030	131,861,714	13,186,171	118,675,542	17,672,768	30,143,994	47,816,778	70,858,764
2031	131,861,714	13,186,171	118,675,542	17,712,957	30,275,226	47,988,198	70,687,344
2032	131,861,714	13,186,171	118,675,542	17,754,833	31,140,101	48,894,950	69,780,592
2033	131,861,714	13,186,171	118,675,542	17,798,468	29,804,045	47,602,530	71,073,012
2034	131,861,714	13,186,171	118,675,542	17,843,936	27,000,702	44,844,655	73,830,887
2035	131,861,714	13,186,171	118,675,542	17,891,314	27,000,702	44,892,033	73,783,509
2036	131,861,714	13,186,171	118,675,542	17,940,681	26,432,515	44,373,214	74,302,328
2037	131,861,714	13,186,171	118,675,542	17,992,122	25,737,352	43,729,492	74,946,050
2038	131,861,714	13,186,171	118,675,542	18,045,723	25,042,189	43,087,931	75,587,611
2039	131,861,714	13,186,171	118,675,542	18,101,576	25,042,189	43,143,784	75,531,758
2040	248,647,972	24,864,797	223,783,175	18,159,774	23,999,445	42,159,239	181,623,935
2041	248,647,972	24,864,797	223,783,175	18,159,774	22,609,120	40,768,914	183,014,260
2042	248,647,972	24,864,797	223,783,175	18,159,774	20,871,213	39,031,008	184,752,167
2043	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,846	185,447,329
2044	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,846	185,447,328
2045	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,847	185,447,328
2046	248,647,972	24,864,797	223,783,175	18,159,774	20,176,050	38,335,847	185,447,327

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 is described in the subsequent sub-sections while the detailed results for the analysis are presented in **Volume 2: Master Plan Annexes – Chapter 11.**

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 **1.57** with an assumed discounting rate of 5%. However, at cost of capital of 8% and 10%, the resulting BCs are **1.24** and **1.08** respectively**.** These BC ratios are greater than 1 and indicate financially viability at 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 463,012,165** at 5% cost of capital and **Kshs 151,115,540** 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 **11.24%** 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%	-42,950,506	9%
Reducing the total net income by 20%	-69,568,574	8%
Increasing O&M cost by 20%	3,830,632	10%
10 % shocks		
Increasing the project cost by 10%	188,074	10%
Reducing net income by 10%	-13,120,960	10%
Increasing O&M cost by 10%	24,476,280	11%

The results on **Table 11.7** above show that the Project's viability is affected when subjected to variations of 10% increase on project cost and 20% reduction in net income.

11.2.9 Conclusion of Financial Analysis

The results of the cost-benefit analysis confirm that the project has favourable BC ratios of between **1.57** – **1.08**. The financial analysis confirms that the project has positive NPVs of **Ksh 463,012,165** at 5% cost of capital and **Ksh 151,115,540** at 8% cost of capital and Financial Internal Rates of Return (FIRR) of **11.24** %.

Sensitivity analyses also indicate that the project viability is susceptible to shocks of 10% and 20% on Project Cost and Net Income.

However, it can be concluded that the Project is financially viable.

11.3 Economic Analysis

11.3.1 General

The following sub-sections present the economic analysis of the selected Wastewater Management Scheme for Lamu Island. 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 Economic Analysis is given in **Volume 2: Master Plan Annexes – Chapter 11.**

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; and
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 Period	Distribution of Investments	Percentage of Disbursement	Sewerage system	Wastewater Treatment Plant	Land
2021	Medium Term Investment	25%	66,391,076	67,440,416	75,000,000
2022		25%	66,391,076	67,440,416	
2023		25%	66,391,076	67,440,416	
2024		25%	66,391,076	67,440,416	
2026	Long Term Investment	10%	16,397,155	21,439,448	
2027		10%	16,397,155	21,439,448	
2028		10%	16,397,155	21,439,448	
2030		15%	24,595,732	32,159,172	
2031		20%	32,794,310	42,878,896	
2032		25%	40,992,887	53,598,620	
2033		10%	16,397,155	21,439,448	
Total			**429,535,853**	**484,156,144**	**75,000,000**

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

	Costs (Kshs)		
Year	Capital Cost	O & M costs	Total cost
2021	276,114,924		276,114,924
2022	276,114,924		276,114,924
2023	276,114,924	24,112,681	300,227,605
2024	276,114,924	24,136,794	300,251,718
2025	0	24,160,931	24,160,931
2026	73,992,925	24,185,092	98,178,017
2027	73,992,925	24,209,277	98,202,202
2028	73,992,925	24,233,486	98,226,411
2029	0	24,257,720	24,257,720
2030	110,989,387	24,281,977	135,271,364
2031	147,985,850	24,306,259	172,292,109
2032	184,982,312	24,330,566	209,312,878
2033	73,992,925	24,354,896	98,347,821
2034	0	24,379,251	24,379,251
2035	0	24,403,630	24,403,630
2036		24,428,034	24,428,034
2037		24,452,462	24,452,462
2038		24,476,914	24,476,914
2039		24,501,391	24,501,391
2040		24,525,893	24,525,893
2041		24,525,893	24,525,893
2042		24,525,893	24,525,893
2043		24,525,893	24,525,893
2044		24,525,893	24,525,893
2045		24,525,893	24,525,893
2046		24,525,893	24,525,893

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 below shows the projections of water demand and supply, and wastewater generation under both ideal and realistic situations of water supply and sewer connections.

Table 11.10: Projected Water and Wastewater conditions

Scenario	2015	2020	2025	2030	2040
	m^3/d				
Projected Water Demand	2,571	3,123	3,817	4,689	7,173
Projected Water Supply	961	1,169	1,436	2,719	5,469
Wastewater Generation with Regular Water Supply & 100% Sewer Connections	2,306	2,776	3,368	4,137	6,229
Wastewater Generation with projected build-out of Sewer Connections and Suppressed Water Supply	942	1,116	1,371	2,418	4,560

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

Lamu Island 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

11.3.9.1 Improvement of Water Bodies (non-use value)

Tourism is one of the economic activity in Lamu Island. At present, raw sewage is released into the environment. The implementation of the proposed Wastewater Management Scheme will ensure proper treatment and disposal of wastewater and result to clean and more attractive environment with the effect of boosting the economy of Lamu Island through increased number of visiting tourists and investors.

It has been assumed that the tourists and visitors to Lamu Island 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.

11.3.9.2 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 Lamu Island results from waterborne diseases and health expenditure per capita per year is USD 13 (Kshs. 975).

11.3.10 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.

11.3.10.1 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	152,581,492	-	152,581,492	39,348,365	12,120,000	12,253,981	63,722,347	-88,859,146	-88,859,146	20,947
2022	152,581,492	-	152,581,492	39,348,365	12,120,000	12,768,649	64,237,014	-88,344,478	-88,344,478	21,827
2023	152,581,492	17,433,327	170,014,820	39,348,365	12,120,000	13,304,932	64,773,297	-105,241,522	-105,241,522	22,743
2024	152,581,492	17,462,024	170,043,517	48,335,397	12,120,000	13,863,739	74,319,136	-95,724,381	-95,724,381	23,699
2025	-	17,494,857	17,494,857	69,990,943	12,120,000	14,446,016	96,556,959	79,062,102	79,062,102	24,694
2026	37,836,603	17,527,573	55,364,176	69,990,943	12,120,000	15,067,195	97,178,138	41,813,962	41,813,962	25,756
2027	37,836,603	17,561,663	55,398,266	69,990,943	12,120,000	15,715,084	97,826,027	42,427,761	42,427,761	26,863
2028	37,836,603	17,597,185	55,433,788	69,990,943	12,120,000	16,390,833	98,501,776	43,067,987	43,067,987	28,019
2029	-	17,634,200	17,634,200	123,422,564	12,120,000	17,095,639	152,638,203	135,004,003	135,004,003	29,223
2030	56,754,904	17,672,768	74,427,672	123,422,564	12,120,000	17,830,751	153,373,315	78,945,643	78,945,643	30,480
2031	75,673,206	17,712,957	93,386,162	123,422,564	12,120,000	18,597,473	154,140,037	60,753,875	60,753,875	31,791
2032	94,591,507	17,754,833	112,346,340	123,422,564	12,120,000	19,397,165	154,939,729	42,593,389	42,593,389	33,158
2033	37,836,603	17,798,468	55,635,071	123,422,564	12,120,000	20,231,243	155,773,807	100,138,736	100,138,736	34,583
2034	-	17,843,936	17,843,936	123,422,564	12,120,000	21,101,186	156,643,750	138,799,814	138,799,814	36,070
2035	0.0	17,891,314	17,891,314	123,422,564	12,120,000	22,008,537	157,551,101	139,659,787	139,659,787	37,621
2036	0.0	17,940,681	17,940,681	123,422,564	12,120,000	22,954,904	158,497,468	140,556,787	140,556,787	39,239
2037	0.0	17,992,122	17,992,122	123,422,564	12,120,000	23,941,965	159,484,529	141,492,407	141,492,407	40,926
2038	0.0	18,045,723	18,045,723	123,422,564	12,120,000	24,971,470	160,514,034	142,468,310	142,468,310	42,686
2039	0.0	18,101,576	18,101,576	232,734,502	12,120,000	26,045,243	270,899,745	252,798,169	252,798,169	44,522
2040	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
2041	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
2042	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
2043	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
2044	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
2045	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
2046	0.0	18,159,774	18,159,774	232,734,502	12,120,000	27,165,188	272,019,690	253,859,916	253,859,916	46,436
							NPV	156,527,286	265,939,817	
							ERR	**19%**	**19%**	

11.3.10.2 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 265,939,817** and **Kshs 156,527,286** respectively. These suggest that the Project is economically viable.

11.3.10.3 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 **19%** for both 12% and 10% discount rates. These confirm that the project is economically viable.

11.3.11 Conclusion of Economic Analysis

The results of the economic analysis after including other economic benefits showed that the project have a **positive NPV of Kshs 265,939,817 and EIRR of 18% at 10%** cost of capital.

These indicators confirm that the project is economically viable.

12.0 RECEIVING ENVIRONMENT AND MONITORING PROGRAM

12.1 Introduction

The proposed Wastewater Management Scheme for Lamu involves collection and conveyance system for the wastewater and a centralized Wastewater Treatment Plant at Taifu Area. After treatment, the effluent discharge is proposed to be discharged into Lamu creeks (Indian Ocean), which has been visualized as a future receiving environment of the proposed Wastewater Treatment Plant (WWTP).

The aims of this Chapter include 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 (200 m upstream of the discharge point [background site], at the discharge point and another 200 m downstream of the discharge point), will be required at Lamu creeks during the Receiving Environment Monitoring Program (REMP). Flows, bank stability, 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 of Lamu Creeks (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), and
- 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), and
- 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 analysed 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), and
- cyanide (total) mg/kg.

Where the water is shallow (<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, 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

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 Management System for Lamu Island. The social safeguards in this context include Project Resettlement Impacts.

The implementation of the proposed Wastewater Management Scheme for Lamu entails construction of the following components;

- Waste Stabilization Pond (WSPs) at identified site in Taifu area, Lamu Island
- Trunk, Secondary and Tertiary sewers
- Sewage Pumping Stations at designated locations within Lamu Island

Once commissioned, the scheme, hereafter referred to as the Project, will provide sustainable water-borne sanitation system to Lamu Urban Centre, as a solution to the existing sanitation systems comprising of on-plot sanitation systems 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 proposal 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 OP 4.01 and ranking of Project (high, medium and low risks) as required by Environmental Management and Co-ordination Act (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. Therefore, a full Environmental and Social Impact Assessment (ESIA) should be carried out 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 mechanisms 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 resettlement of persons since the proposed sites for the Wastewater Treatment Plant and Sewage Pumping Stations are privately-owned.

The Project has potential effects on assets and sources of livelihood through;

- Loss of private land at the proposed site for WSP (within Taifu location)
- Loss of structures lying along the sewer alignments and its wayleave and at the proposed WWTP site during the construction period
- Loss of crops and trees lying along the sewer alignments and its wayleave and at the proposed WWTP site during the construction period

The loss of land for the development of Water Treatment Plant is expected to affect the following parcels;

(a) LAMU ISLAND BLOCK V sheet No. 180/4/3 S.K 21
(b) LAMU ISLAND BLOCK VI sheet No. 180/4/2 S.K 21
(c) LAMU ISLAND BLOCK V sheet No. 180/4/7 S.K 21

13.2 Guiding Legislation and Policy

Based on the scope, EMCA 1999 requires that Project activities under the proposed Wastewater Master Plan for Lamu 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 Infrastructural 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 (OP4.36, GP4.36)
- OP/BP 4.04 (Natural Habitats)
- Physical Cultural Resources(OP/BP4.11)
- 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 scope and extent of the Project. The aspects considered during scoping include;

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 Candidate Sites

In the formulation of Wastewater Management Strategies, Taifu site has been identified as a candidate site for the development of Wastewater Treatment Plant. However, an alternative site at Taifu has been assessed for suitability in case availability of land at Taifu is hindered.

The scoping for environment and social impacts has been carried out for the proposed site at Taifu and another alternative site. A summary of the findings for these sites based on scoping is presented in **Tables 13.1** to **13.2** below and **Figures 13.1** below and **Figure 13.2** on **Page 13-4**.

Table 13.1: Site Description – Kisisi (Mwaumi Village)

Site Name	Environment and Social Parameters	Remark
Kisisi site	• No anticipated significant impact to natural environment • Significant impact to Health and Safety of the community • Significant impact to social environment (Land Acquisition and Resettlement)	• Site not suitable for WSP from a Social, Health and Environmental perspective


Figure 13.1: Kisisi Site

Table 13.2: Site Description – Taifu (Matondoni Village)

Site Name	Environment and Social Parameters	Remark
Taifu site	• No anticipated significant impact to natural environment • No significant impact to Health and Safety of the community • No significant impact to social environment, however OP 4.12 is triggered due to isolated households identified on site	• Detailed ESIA required at detailed design stage • Full RAP required detailed design • Site ideal for WSP from Environment and Social perspective

Figure 13.2: Taifu Site

13.3.2 Selected Site

In consideration of the evaluated environmental and social factors, the most appropriate site for the development of Wastewater Treatment Plant is the Taifu Site. It presents the less significant environment and social risks which can be mitigated by undertaking an Environment Assessment and Resettlement Action Plan.

The subsequent sub-section summarizes the Environmental and Social Impact, Resettlement Impacts and their proposed mitigation measure with respect to developing Wastewater Treatment Plant and the selected site and implementing the selected 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 marine pollution caused by discharge of untreated sewage into the coral reef, mangrove forest and sea grasses. Pollution of open storm water drains and water resources within Lamu 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. Lamu Island 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 Wastewater Treatment Plant is potential source of re-charge to the water bodies. If found economically viable at a later stage, the effluent from the Wastewater Treatment Plant can be re-used for farm irrigation and other non-portable 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 Improved Hygiene and Sanitation in the Project Areas

Good Hygiene and Sanitation Standards are linked to provision of sanitation infrastructure. Lamu 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 13.8** below.

Table 13.8: 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**

13.6.5 Reduced Cases of Water Related Diseases

Cases of water borne disease in Lamu 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 13.9** below.

Table 13.9: 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**

13.6.6 Reduced Water and Sanitation Burden to Women

The socio-economic survey undertaken in the Project 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 ensure enhanced family health.

The impact rating for reduced burden to women due to improved water and sanitation system is shown in **Table 13.10** on **Page 13-7**.

Table 13.10: 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**

13.6.7 Increased Land Values in the Project Area

Provision of the sanitation infrastructure to Lamu Urban Centre 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 13.11** below.

Table 13.11: 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 Lamu 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 13.12** below**.**

Table 13.12: 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 Project dimension 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 drainage area of Lamu Island, conveyance to the proposed WWTP for treatment and discharge of treated effluent to the Indian Ocean.

During the construction period, effluents from construction plant and equipment (oils, grease, hydro-carbonates) are potential point pollutants of water resources. These effluents originate from activities such as cleaning, repair of the equipment as well as through 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 13.13** below.

Table 13.13: 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 13.14** below.

Table 13.14: 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 13.15** below.

Table 13.15: 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 Local Authority.

- 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 13.16** below.

Table 13.16: 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 requires land acquisition for construction of the proposed Pumping Stations and the Wastewater Treatment Plant at Taifu. Project components such as Sewers will also trigger loss of land and private assets and sources of livelihood.

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 13.17 below presents a summary of Resettlement Impacts identified for the site at Taifu;

Table 13.17: Resettlement Impacts – Taifu Site

Site Name	Category of Loss Identified	Extent and Magnitude of Loss	Land Details
Taifu	• Loss of Land (WWTP site) • Loss structures (along road reserves) • Loss of crops and trees (along road reserves and WWTP site)	Land requirement approximately 15Ha	• LAMU ISLAND BLOCK V sheet No. 180/4/3 S.K 21 • LAMU ISLAND BLOCK VI sheet No. 180/4/2 S.K 21 • LAMU ISLAND BLOCK V Sheet No. 180/4/7 S.K 21

The Impact Rating for Resettlement Impacts is shown in **Table 13.18** below.

Table 13.18: 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 13.19** below.

Table 13.19: 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 a potential of increasing transmission of HIV/AIDS and other sexually transmitted diseases (STDs).

Impact rating for increased transmission of HIV/AIDS is as shown in **Table 13.20** below.

Table 13.20: 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 13.21** below.

Table 13.21: 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 13.22** below.

Table 13.22: 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 Healthy 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 13.23** below.

Table 13.23: 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 • Regular inspection of the sewer pipeline corridor for encroachment. • 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 Lamu Water and Sanitation Company (LAWASCO).
Risk of Sewer blockage and overflows to the environment	• Awareness rising among community members not to dump solids in manholes and to report any blockages to the LAWASCO • Regular cleaning of grit chambers and sewer lines to remove grease, grit, and other debris that may lead to sewer backups • 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 • 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 Wastewater Treatment Plants	• Keep the WWTP clean to limit the attraction of birds which scavenge for insects and maggots from the ponds and sludge beds • WWTP should be protected from wildlife encroachments by providing secure barriers • The quality of treated effluent before discharge into the ocean be considered an important parameter for the control of the ocean shoreline eutrophication. • 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 man hole step irons)	• Manhole covers and step irons where made of steel are prone to vandalism and pilferage • Manhole covers and manhole step bars should be made of alternative material such as high density plastic which has low scrap resell value
Air pollution from odour emanating from Wastewater Treatment Plant	• Plant trees especially bamboos and eco-friendly indigenous trees around the WWTP for odour control and breaking wind • Ensure appropriate covering/ventilation of pre-treatment unit; • Ensure appropriate handling and removal of grit/grease; • Ensure proper sizing and alignment of the lagoons • Ensure scum is appropriately disposed of or properly stabilized; • Ensure that the pond series have adequate water flow and aeration to reduce the potential of odour formation; • Construct roofs over the Sludge Drying Beds to protect drying of sludge from precipitation
Land and Soil Contamination	• LAWASCO to attend to sewer bursts promptly pipes promptly • Provide high risk areas with appropriate drainage for effective channelling of burst sewage spills; • Encourage land owners along sewer lines to maintain vegetated belts along the pipeline to control any overflows flows and trap soil. This is to include protection of sewers • 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 Wastewater Master Plan for Lamu Island.

The Project components involved include;

- Waste Stabilization Pond (WSP) at Taifu area
- 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 13.24** on **Page 13-14**.

Table 13.24: Project Resettlement Impacts for Master Plan Projects

Project Component	Category of Loss	Land Requirement (Ha)	WWTP Land Ownership
Waste Stabilization Pond (WSP)	• land acquisition anticipated • Loss of crops and trees	15Ha	Private Land: • LAMU ISLAND BLOCK V sheet No. 180/4/3 S.K 21 • LAMU ISLAND BLOCK VI sheet No. 180/4/2 S.K 21 • LAMU ISLAND BLOCK V sheet No. 180/4/7 S.K 21
Trunk, secondary and tertiary sewer lines	• Loss business structures • Loss of crops and trees	N/A	Road reserves land and river riparian land
Pumping Stations	• Land Acquisition required • Loss business structures • Loss of crops and trees	1.5	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 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 Matric on **Table 13.25** on **Page 13-16** to **13-18**.

Table 13.25: 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 • 15% cash top up in compulsory acquisition • Cash compensation for standing assets • Administrative charges, title fees, or other legal transaction costs • Money Management training
		(b)Tenant (c) Lease holder	• Cash compensation for standing assets • Administrative charges or other legal transaction costs • One month notice to vacate • Money Management training
		d)Informal Settlers	• Cash compensation for standing assets • One month notice to vacate • 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 • Replacement cost for standing assets erected by the Land Owner • 15% cash top-up in compulsory acquisition • Administrative charges, title fees, or other legal transaction costs • Money Management training
		(b)Tenant (either residential or business) (c)Lease holders	• Replacement cost for standing assets • Administrative charges or other legal transaction costs for registered leases • One month notice to vacate • Money Management training • Relocation assistance
		(d)Informal Settler	• Replacement cost for standing assets • Possibility of land grant where possible alongside relocation and assistance with livelihood restoration • One month notice to vacate • 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 • Repair costs for unaffected structure or cash equivalent to 25% of the compensation • Right to salvage material plus relocation costs.

	Type of Loss	Unit of Entitlement persons	Entitlements
		(b)Owner without titles	• Cash compensation at replacement cost for affected portion based on market value without depreciation • Repair costs for unaffected structure or cash equivalent to 25% of the compensation • 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 • Repair costs for unaffected structure at 25% compensation • Right to salvage material plus relocation costs • 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 • Right to salvage materials without deduction from the compensation package • One month notice to vacate • Relocation assistance
		(b)Tenant/Lease Holder	• Cash compensation for remaining lease/deposits • Right to salvage materials • One month notice to vacate • Relocation assistance
C. Movable / Mobile structures			
5		**Kiosks or Stalls**	• Cash Compensation of comparable replacement sites • 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 • Allowed adequate time to harvest the crop and trees. • 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) • Livelihood restoration measures as identified in section 5.3 (above)

Type of Loss	Unit of Entitlement persons	Entitlements
	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) • Informal employees: one month minimum wage • 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
G. Assistance to vulnerable groups	Vulnerable group	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 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

[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 13.26** below.

Table 13.26: Monitoring Indictors During and After Compensation Payments

Resettlement Compensation Payment Period	Post-resettlement Compensation Payment Period
• Number of PAPs compensated • Number of PAPs who have acquired legal papers to new property • Number of PAPs who have restored their livelihood enterprises • Number of PAPs who have registered grievances with the GO • Number of PAPs whose grievances have been resolved • Number of vulnerable PAPs or groups identified and assisted during compensation payments	• Number of PAPs with successfully restored livelihoods and assets, • Number of PAPs who have maintained social and cultural ties, • No of PAPs whose grievances have been resolved or otherwise, • Number of vulnerable groups assisted and restored livelihood enterprise and assets.

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 a Wastewater Management Infrastructure based on current international best practice that is applicable to CWSB and LAWASCO.

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 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 includes:

- 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 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 14.1** on **Page 14-2.**

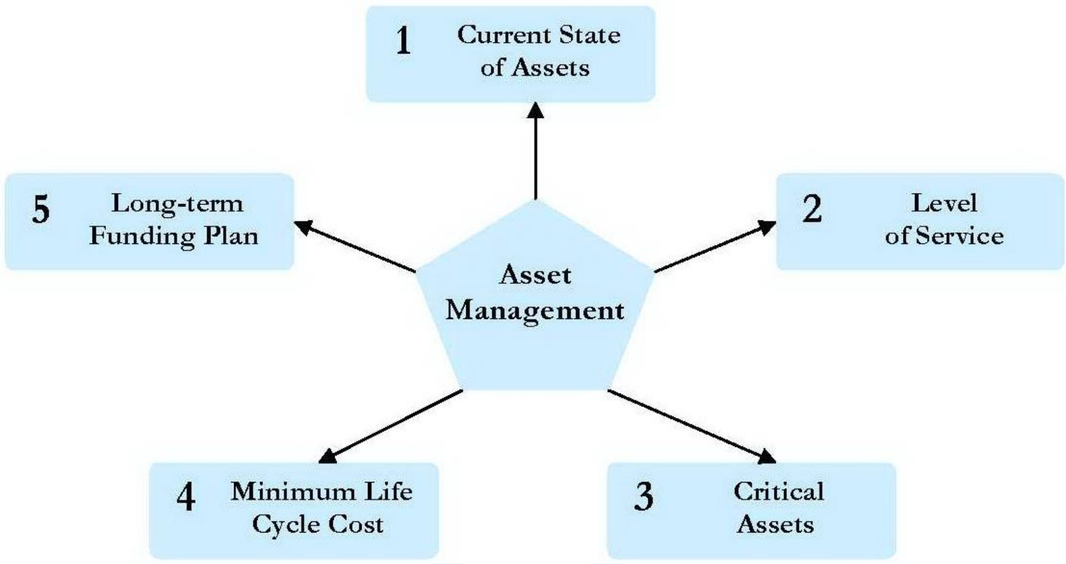


Figure 14.1: Core Aspects of Asset Management Framework

This framework covers all the major activities associated with asset management and can be implemented with a level of sophistication applicable to any given water supply system 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 LAWASCO and CWSB reports and stakeholders involved in the service provision and consumption.

The sustainable level of service needs need 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 system’s 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 **14.2** 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 system 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.

Where AMP fits into the operational, facilities'' management and strategic sectors of the entity is as shown in the **Figure 14.3** on **Page 14-6**.

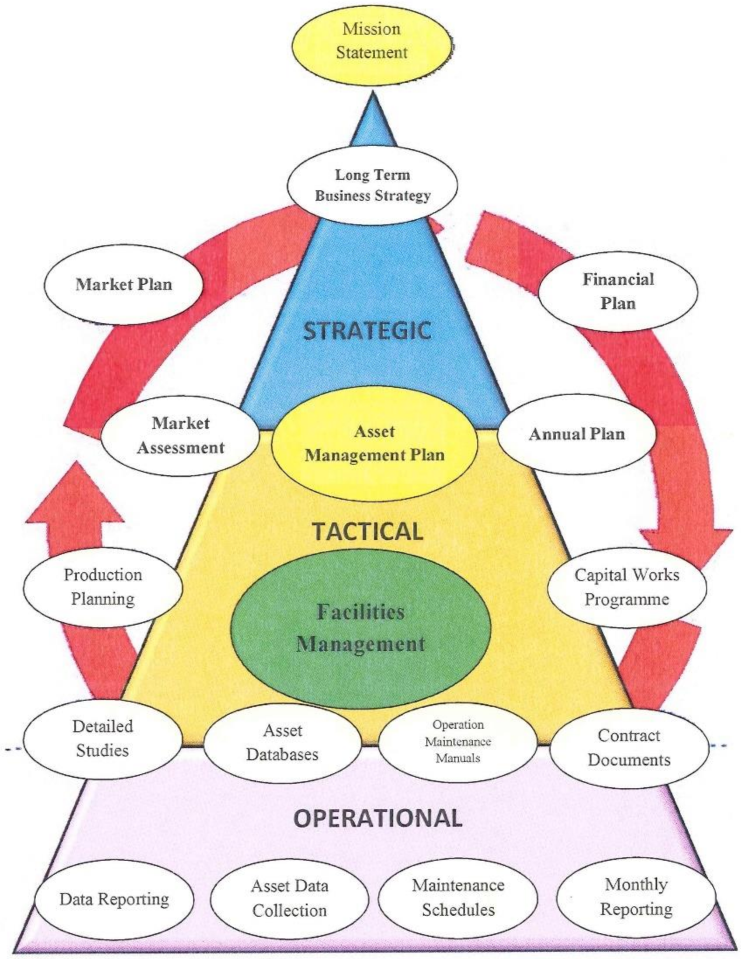


Figure 14.3: Where the AMP Fits In

14.9 CWSB Asset Management Plan Situation

Currently CWSB or LAWASCO does 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 LAWASCO 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 WSPs and procedures for the regular updating and modification of the AMP in the future as needs and infrastructure changes.

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.

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 more elaborately defined as follows 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 complex and may result 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 of factors.

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 countermeasures. 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.

[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.

The risks from climate change can therefore be summarized as follows:

- 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 wastewater 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 the Preliminary ESIA for the Selected Wastewater Management Schemes.

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.

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 effluent discharge point and 200m upstream.

- Proper operation and maintenance of the Wastewater 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 of the water resources need to be analysed and made available on a regular basis to all authorities involved in the management of 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 Lamu 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 System 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***) 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 meeting future water demand that is best suited to manage the potential risks.

15.3.2 Key Issues and Recommended Actions

a. Wastewater Management Scheme 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 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. 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 water resources 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 measures for chronically prone areas to flooding and drought. Several main actions may be concurred to achieving this goal. The creation of mechanisms of regional consultation, regional solidarity funds, drought and flood preparedness programs and early warning systems, mitigation plans at local and national levels, regional emergency funds and insurance programs for extreme events could be considered.

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/leak reduction, 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. 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 15.2** below.

Table 15-2: 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 (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) (c) All legally required permits obtained for construction and/or rehabilitation (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. (e) Workers' PPE comply with international good practice (always hardhats, as needed masks and safety glasses, harnesses and safety boots) (f) Appropriate signposting 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 (b) During project construction dust be suppressed by ongoing water spraying and/or installing dust screen enclosures at site (c) The surrounding environment (sidewalks, roads) be kept free of debris to minimize dust (d) No open burning of construction / waste material at site (e) No excessive idling of construction vehicles at sites
	Noise	(a) Construction noise be limited to restricted times agreed to in the permit (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. (b) Mineral construction and demolition wastes be separated from general refuse, organic, liquid and chemical wastes by on-site sorting and stored in appropriate containers. (c) Construction waste be collected and disposed properly by licensed collectors

ACTIVITY	PARAMETER	MITIGATION MEASURES CHECKLIST
		(d) Records of waste disposal be maintained as proof for proper management as designed. (e) Whenever feasible the contractor to reuse and recycle appropriate and viable materials (except asbestos)
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 (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 (c) Monitoring of new wastewater systems (before/after) will be carried out (d) Construction vehicles and machinery will be washed only in designated areas where runoff will not pollute natural surface water bodies.
C. Physical cultural (s)	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. (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 wastewater 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 Lamu Island 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 4Nr Ablution Blocks at selected 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 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
4	6	2	720	62,000,026	601,942

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	35,499,980	344,660
2	Sludge Drying Beds	• 4 Beds; each 13 x 10m		
3	Twin-Septic Tanks	• 2 Tanks; each 98 m³ capacity		
4	Land Requirement	• 0.5 Ha		
5	Exhaust Discharge Tanker	• Minimum 1 Nr (Either owned by LAWASCO or Private Providers)	-	-

To provide a sustainable sanitation system, a centralized Wastewater Management Scheme comprising of a gravity sewage conveyance system and a Waste Stabilization Ponds system (ultimate capacity – 4,600 m³/d) at undeveloped land in Taifu area has been selected as the suitable Wastewater Management Scheme.

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 including the associated costs in the 2 Phases are given in **Table 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	• 15 Ha	610,325,969	5,925,494
2	Sewers	• 225 – 450 mm Dia; Total length 13 km		
3	Pumping Main	• 100 mm Dia; Approx. Total Length 220 m		
4	Wastewater Treatment Plant	• Waste Stabilization Ponds; Capacity 2,300 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 mm Dia; Total length 7 km	378,366,027	3,673,457
2	Pumping Main	• 100 mm Dia; Approx. Total Length 1,085 m		
3	Wastewater Treatment Plant	• Waste Stabilization Ponds; Capacity 2,300 m³/d		

Financial analysis of the selected Wastewater Management Scheme presented the following Financial Ratios / Performance Indicators;

- **Benefit – Cost (BC) Ratio;** 1.57 – 1.08
- **Net Present Values (NPV);** Ksh. 463,012,165 @ 5% cost of capital
  Ksh. 151,115,540 @ 8% cost of capital
- **Financial Internal Rate of Return (FIRR);** 11.24%

On the other hand, economic analysis presented the following Performance Indicators;

- **Net Present Values (NPV);** Ksh. 265,939,817 @10% cost of capital
- **Economic Internal Rate of Return (EIRR);** 19 %

Sensitivity analyses also indicate that the project viability is susceptible to shocks due to Project Costs and Net income

However, it can be concluded that the selected scheme is both financially and economically viable.