Greening Uganda's Urbanization and Industrialization

Development of Green Industrial Masterplans, Infrastructure plans and project concept notes for Entebbe, Pakwach and Soroti

Water and Sanitation Assessment

(Storm water, Water supply, Wastewater and Solid waste management plans)

Final Report for Soroti Industrial and Business Park

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28th December 2023

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List of Abbreviations and Acronyms

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
GGGI	Global Green Growth Institute
IBP	Industrial and Business Park
m	Meters
MDD	Maximum Day Demand
NWSC	National Water and Sewerage Corporation
SW	Solid Waste
SWM	Solid Waste Management
UIA	Uganda Investment Authority
WSP	Waste Stabilization Ponds
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1. Introduction

1.1 Background

Based in Seoul, the Global Green Growth Institute (GGGI) is an intergovernmental organization founded to support and promote green growth. It targets key aspects of economic performance such as poverty reduction, job creation, social inclusion, and environmental sustainability. GGGI works with countries around the world, building their capacity and working collaboratively on green growth policies that can impact the lives of millions. The organization partners with countries, multilateral institutions, government bodies and the private sector. This is to help build economies that grow more economically and efficiently. Ultimately, they become more effective and sustainable in the use of natural resources, less carbon intensive, and more resilient to climate change. GGGI is partnered with the European Union (EU) as part of the EU inclusive green economy uptake programme (GreenUP). At present, it delivers a project entitled “greening Uganda’s urbanization and industrialization” (2020-2023). The programme is aligned with the government of Uganda’s vision 2040, the third National Development Plan (NDP III), and the Uganda green growth development strategy (UGGDS). The project promotes sustainable development and inclusive green growth in Uganda. It focuses on green city development, green industrialization, efficient waste management and green growth integration into planning and budgeting.

1.2 Project Objective

The main objective of the project is to develop green masterplans, symbiotic infrastructure plans and infrastructure project concept notes for the 3 locations. The project hopes to support the development of 3 industrial locations at Entebbe, Soroti and Packwach to support Uganda in becoming mid-income status via industrialization. Therefore, the overall goal is to design the infrastructure to allow the industrial park and its contextual city to thrive, as an economic system. The status of delivery of the specific objectives of the water and sanitation assessment is presented below.

Table 1-1: Assignment objectives and current status of delivery of outputs

#	Specific objective	Current status
1	Preparation of draft inception report	Completed, **29th July 2023**
2	Preparation of final inception report	Completed, **29th July 2023**
3	Site visits, detailed field data collection, and stakeholder engagements	July – August 2023 Additional stakeholder engagements in Entebbe were completed in September 2023
3	Preparation of detailed methodologies for water and sanitation data collection and analysis (or modelling) Preparation of outline designs and master plans for water supply, wastewater collection and treatment, stormwater, and solid waste management for each of the three sites.	Completed, **18th August 2023**
4	Preparation of the proposed water and sanitation infrastructure lay outs/plans	Draft Report for Soroti Industrial Park completed on **12th October 2023** **Revised Draft Report for Soroti Industrial Park submitted on 11th November 2023** **Final Report submitted on 28th December 2023**
5	Preparation of brief environmental impact assessment of the plans	Green infrastructure plans included in final revised water and sanitation assessment report, submitted on **28th December 2023**
6	Development of project concept notes for water and sanitation infrastructure	Draft project concept notes submitted on **11th November 2023** **Final project concept notes submitted on 28th December 2023**

1.3 Soroti Industrial and Business Park

This report presents the draft findings of the water and sanitation assessment for the 0.88 km^2 Soroti Industrial and Business Park (IBP), which is situated in the Eastern Uganda. The park is strategically located just 5 km, North of Soroti Town in Temere, Arapai Sub-County and approximately 4 km from Soroti air strip. The park is also located in close proximity to several educational institutions, including Soroti University, Teso College Aloet and Busitema University. Figure 1-1: Location of the Soroti Industrial and Business Park shows the location of the Soroti Industrial and Business Park.

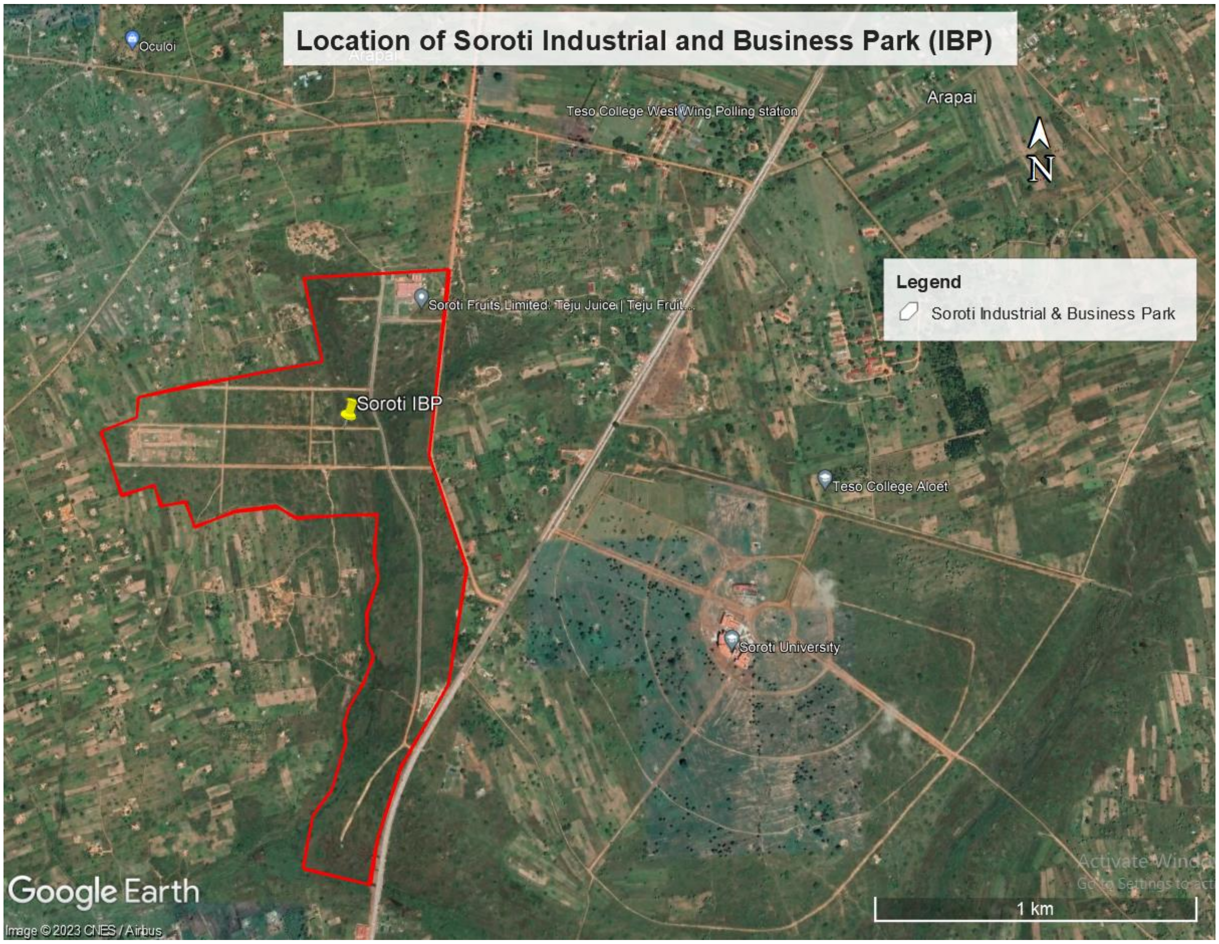

Figure 1-1: Location of the Soroti Industrial and Business Park

1.4 Current Status of the Soroti IBP

According to the 2021 status report of industrial and business parks prepared by UIA, the master plan and environmental impact assessment (EIA) of the Soroti Industrial and Business Park have been successfully completed, and cadastral surveys of the plots have been finalized. Border markers were installed around the park, ensuring clear demarcation and essential utilities like water and power have been extended to the park, facilitating its functionality. The park features established access roads, along with the availability of both road infrastructure and power supply. Currently, there are 2.2 km of paved roads including Temele Industrial Road, Pineapple Lane, and Palm Tree Close and 4.4 km of gravel roads that have been opened.

One of the main factories within the park is the Soroti fruit juice factory which produces ready-to-drink "TEJU" juice from concentrate and puree using locally grown fruits, . Currently, the operational industries include; Soroti Fruit Factory (TEJU), Sanqua Engineering, Asalalamaal Ltd, the National Industrial Hub under the Office of the President, and PELA Commodities Ltd. Figure 1-2 shows the proposed Soroti Industrial and Business Park Master Plan with the land allocation to the different industries. The consultant shall develop water and sanitation infrastructuremaster plans and associated water infrastructure project concept notes for the Soroti Industrial Park, based on the principles of resource efficiency and green green growth

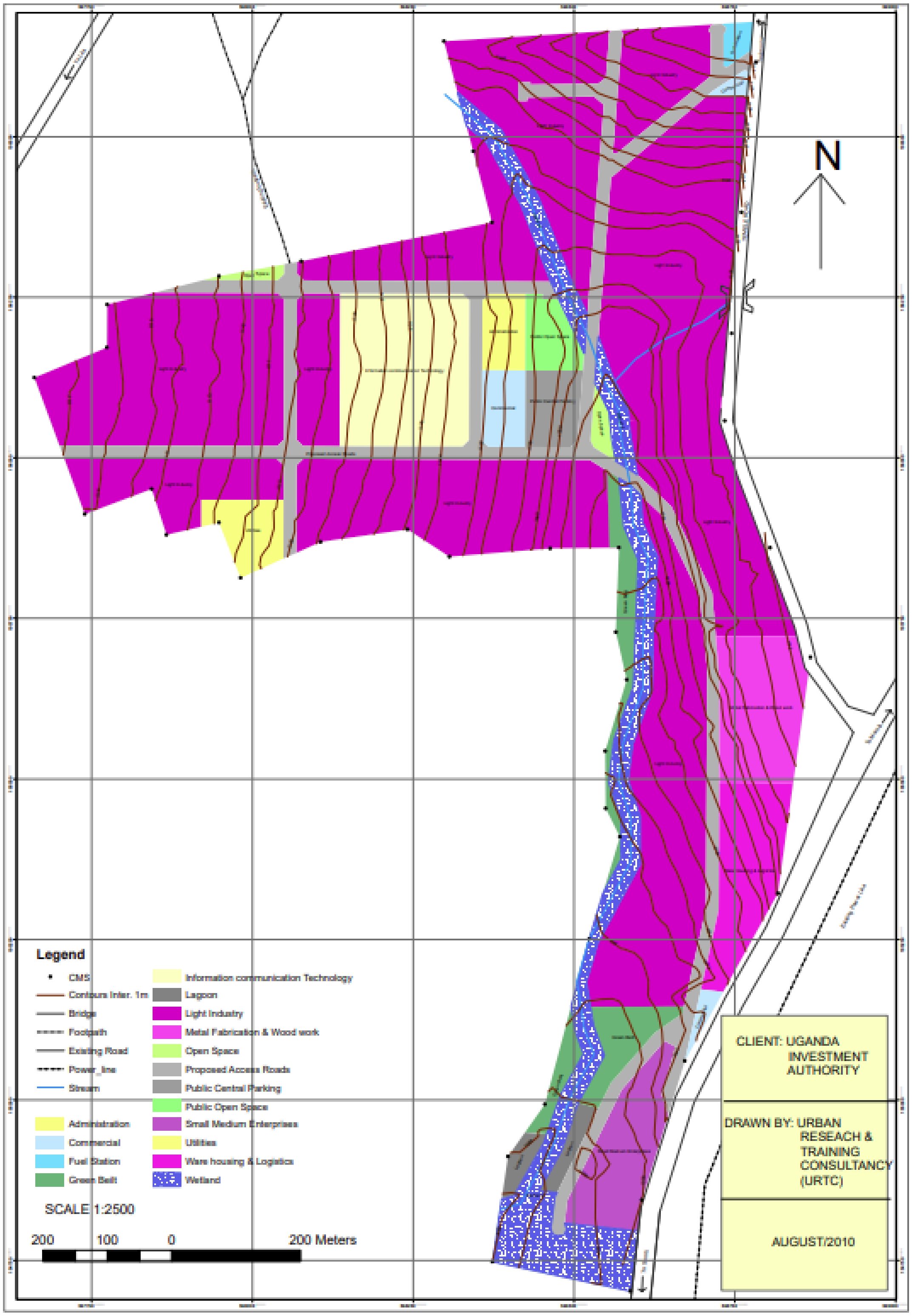

Figure 1-2: Soroti Industrial and Business Park Master Plan

Source: URTC

Table 1-2: Operational Status of the Industries in Soroti Industrial Park

Industry	Business Activity	Status
Uganda Development Corporation &Teso Fruit (Teju Juice)	Agro-processing	Operational
Pela Commodities Ltd	Factory in the grain value chain	Operational
Sanqua Engineering Limited	Production of concrete products	Construction Stage
Asalalamaal Ltd	Manufacture of vegetable and animal oils and fats	Construction Stage
Soroti District Local Government	Skilling Youth	Construction Stage
Teso Foods Ltd	Fruit processing plant	Construction Stage
Jena Herbals (U) Ltd	Manufacturing facility for Covidex and other health products	Construction Stage
Uganda Free Zones Authority	Free Zone Area	Pre-Start Stage
Keliz Hotel Limited	hotel	Pre-Start Stage
Keliz Medical Equipment Ltd	Hospital	Pre-Start Stage
Mega Holdings	Agro-processing	Pre-Start Stage
Soroti Teachers Co-Op Savings & Credit Society Ltd	Co-Operatives	Pre-Start Stage
Wodma Investment Ltd	Building and Construction Plant	Pre-Start Stage
Star Tahina Ltd	Food processing plant	Pre-Start Stage
Komolo Foods And Beverages Ltd	Grain and Fruit Processing	Pre-Start Stage
National Muslim Women Development Council	Developing a Regional Agricultural Mechanization Equipment Centre	Pre-Start Stage
Serere Agro Enterprise Limited	Agro Processing and Bulk Grain Handling	Pre-Start Stage
Wash And Wills Country Home Ltd	Hotel	Pre-Start Stage
Operation Wealth Creation/Naads	Cassava processing factories	Pre-Start Stage
Sukuma (U) Ltd	Factory to manufacture drugs, fertilizers, nitrogen compounds, packaging and distribution	Pre-Start Stage
Goldseed International Ltd	Agro processing factory	Pre-Start Stage
Soroti Fruits Limited	Expansion of the existing agro-processing factory	Pre-Start Stage
AZ Plumbing Company Ltd	Manufacturing plant for organic fertilizer and biogas	Pre-Start Stage
Proposed SME Land	SME activities	

1.5 Stakeholder Identification and Engagement

Stakeholder identification and engagement was undertaken to identify and understand the needs, priorities, and concerns of the relevant stakeholders. A field mission was conducted in Soroti from August 9th to 11th, 2023, encompassing visits to various locations, including Soroti Industrial Park, Aminit Landfill site, the Dairy Development Authority, and stakeholder interactions at the Hursey Resort Hotel. The purpose of the field mission was to assess the water and sanitation requirements for the industrial park. The main activities that were undertaken during the field mission included: field visits and assessment of water and sanitation infrastructures for Soroti Industrial Park, stakeholder engagements, visit to Soroti Fruit Factory and Aminit Landfill site. The findings highlighted the need for improvements in solid waste management, wastewater treatment and stormwater drainage within Soroti Industrial Park and the broader Soroti City area. In addition, the industrial park shall require a stable and reliable supply of potable water when fully developed. After the field mission, there were further engagements and consultations that were held in Kampala with the various stakeholders such as Mega Holdings Ltd, Teso Foods, etc. Additionally, the consultant managed to reach out to the contact persons of most of the industries in order to determine their operational status and the main products dealt in.

1.5.1 Findings from the stakeholder engagement

The management of the park transitioned from the district administration to the city administration in 2018 following Soroti's declaration as a city. Currently, there are three operational factories within the park; Soroti Fruit Factory, Sanqua Engineering and Pela Commodities Limited, utilizing municipal water from the National Water and Sewerage Corporation (NWSC) as their main water source. Additionally, a borehole serves the neighbouring communities around the Industrial Park.

The management of solid waste in Soroti City involves a central hub, the Aminit Landfill site, which handles waste from various sources, particularly Soroti Market, contributing the largest share. Initially, it was believed that solid waste from the Industrial Park was also directed to Aminit Landfill. However, further investigation revealed that all solid waste generated by the Soroti Fruit Factory, within the Industrial Park, is actually deposited at a distinct landfill known as Telangot. The type of waste that is being dumped at Telangot site is composed of flammable citrus peel that pauses a considerable risk of fire outbreaks to the neighbouring communities.. It should therefore be noted that the Telangot site is not suitable for landfilling in the future due to the unacceptable conditions..

At Aminit Landfill site, separation, sorting and composting of waste is done by casual labourers who lack the requisite personal protective equipment (PPE) and who are exposed to significant health risks caused by unsafe landfilling operations. The solid waste is moved around the landfill site by a wheel loader which occasionally lacks fuel and this leaves the waste unattended to. However, the consultant could not validate whether the solid waste management activities (separation, sorting and compositing) are executed efficiently based on documented evidence.

Currently, Soroti Industrial Park lacks a comprehensive stormwater drainage masterplan. Side drainage systems have been implemented along access roads within the park, guiding rainwater downstream to transport runoff from storm events. The park is intersected by a natural stream, and during intense rain events, flooding is observed in the downstream areas near the wetland.

Figure 1-3: Cross culvert discharging runoff into the wetland

Figure 1-4: The downstream wetland

There is an existing wastewater treatment plant (WWTP) within Soroti Fruit Factory which treats the wastewater generated from the various processes at the factory. However, the plant is insufficient and the treated wastewater does not meet the environmental standards, resulting in complaints from neighbouring residents about foul odours. Additionally, when tests were conducted on the effluent from the WWTP, the results indicated that the BOD and COD content of the wastewater were 300mg/l and 700mg/l respectively which is extremely higher than the minimum allowable levels prescribed by NEMA.

1.5.2 Aminit landfill site visit

The consultant visited the Aminit landfill site in Soroti city. The solid waste dumped at Aminit land fill is collected from Soroti city and market. Based on the stakeholder engagements, the consultant confirmed that one truck transports the solid waste from Soroti Market to Aminit Landfill site, making approximately 6-7 trips weekly. The main activities taking place include waste sorting, composting, and landfilling. However, these activities are being undertaken inefficiently as described below. Sorting and recycling of the solid waste is done by casual labourers who lack the proper equipment and protective gear and often get exposed to escaping gases, untreated leachate and also harmful physical waste such as broken glass or metal. In addition, the landfill site pauses a great security risk from illegal sorting activities which are in some instances undertaken by children who illegally access the site and undertaking scavenging and sorting activities without adequate personal protective equipment. Amongst all the recycling opportunities, metal recycling is frequently carried out due to due access to a ready market for scrap metal.

The second activity that is taking place at the site is composting which received support from USAID for the set up. However, the operation and maintenance of the composting facility is grossly inadequate and has not achieved its intended objectives. This was partly attributed to lack of centralised solid waste operations management system and insufficient funding for operations and maintenance of the facility

The third activity is landfilling. Landfilling is also not adequately undertaken. In addition, the landfill is prone to risk of fire outbreaks due to dumping of flammable materials and lacks water supply for use by the workers.. In addition, the landfill generates leachate which poses significant health risks to the causal laborers who lack personal protective equipment. Due to the inadequate land filling operations, solid waste that is primarily collected from Soroti market undergoes decomposition at the site and is transformed into manure of poor quality that is graded into two grades that is A and B. Based on the field findings and desk analysis undertaken by the consultant, it is concluded that the Aminit landfill in its current state is unsuitable for handling solid waste generated from Soroti industrial park and therefore requires major upgrading. This therefore presents an opportunity for developed of symbiotic solid waste management infrastructure.

1.5.3 Assessment of existing storm water drainage system

Currently, there are access roads within the park for ease of transportation. The access roads around the Soroti Fruit Factory are tarmacked and these are equipped with side drains designed to channel runoff water downstream towards the swamp, which is a vital component of the drainage infrastructure. However, the open drains are often blocked due to deposition of solid waste and sediments. It was also observed that wastewater from the Soroti Fruit Factory is being discharged into the stormwater channels, potentially contributing to water quality issues and necessitating further evaluation. This problem shall require construction of separate sewer network for collection and transport of waste water to the collection wastewater treatment plant. Additionally, interviews conducted during the assessment revealed a recurring problem of flooding downstream during periods of heavy rainfall, highlighting the need for improved stormwater management, for example through implementation of blue-green infrastructure such as bioswales, rainwater harvesting and construction of centralised storm water detention pond This has been taken into considering in development of the storm water infrastructure concept notes. Lastly, the inspection uncovered evidence of siltation within the stormwater drains. This could be attributed to inadequacies in the design or insufficient system cleaning and maintenance operations. The consultant therefore recommends formulation and implementation of improved storm water system cleaning and maintenance system that will ensure periodic cleaning and removal of solid waste and sediments from the existing storm water system to as to enhance its efficiency and functionality.

2. Potential Sectors

2.1 Introduction

Key sectors for development to be set up in the Soroti Industrial Park were identified based on extensive discussions, site assessments, socio-economic and environmental analyses. The proposed sectors include; fruits and vegetables, food/grains, concrete, dairy, fish, herbal medicine, seed oils and the domestic sector. The water supply requirements, wastewater generation and treatment, and solid waste management assessment are described in detail based on the findings of the sectoral analysis.

2.2 Dairy Sector – Yoghurt, Ice cream, Bulking and Cooling

Currently, the Dairy Development Authority operates a milk cooler machine at its premises in Soroti city. The facility is used for milk cooling and production of ice cream and yoghurt are produced on small scale. The dairy sector will potentially benefit from the Industrial Park, with the expected processes at the site to include storage, bulking, cooling and production of yoghurt and ice cream.

A 10,000 liter capacity cooler was considered for this study. In addition, the quantity of milk to be processed into yoghurt and ice cream was determined as 8,000 litres and 4,000 litres respectively.

Wastewater generated from the dairy sector will originate from milk bulking and cooling operations as well as pasteurisation and processing activities. This wastewater will be characterized by its high organic load, nutrient content (particularly nitrogen and phosphorus), typically lower pH, variable temperature, elevated biological oxygen demand (BOD), suspended solids and oil and grease.

2.3 Fruits and vegetables – Sorting, Washing, Processing and Packaging

The value chain of fruit and vegetable production involves various stages, including sorting, cleaning, grading, peeling, extraction of juice, packaging, stacking, inspection and storage.

The stakeholder engagement with Soroti Fruit Factory provided an estimation of the quantity of fruits processed per season to produce concentrate, puree and ready to drink juice. 305 tonnes of oranges and 350 tonnes of mangoes are collected per season and processed into concentrate and puree. This report therefore has been prepared on the final quantities as provided by the team sector analysis with a production capacity of 320 tons per day.

The sector will rely heavily on adequate water supply for cleaning the fruits and dilution of concentrate. Additionally, the sector must tackle solid waste generated during the sorting, cleaning, peeling and packaging processes; therefore, segregation, proper disposal and recycling methods for waste materials should be established to prevent land/ water pollution and minimise fire risks. The wastewater generated from these processes has a high content of BOD and COD; consequently, it is recommended that pre-treatment of this wastewater is done so that the wastewater released has a lower concentration of pollutants. Similarly, treatment of this wastewater generated afterward is vital to minimise any discharge of pollutants to the environment.

The solid waste generated from these processes include fruit peelings, vegetable trimmings, organic chippings, seeds, packaging materials. Some of this waste will be valorised for instance oils will be extracted from orange peelings, butter extracted from mango kernel and this will reduce on the amount. Plastic packaging material will be collected by agents and taken to recycling companies for generation of new products.

Wastewater produced during the processing of mangoes for concentrate and oranges for puree and juice tends to have a substantial amount of organic content, including sugars, organic acids, and remnants of fruit pulp. Additionally, it may contain solid components like fruit peels, seeds, and residual pulp, contributing to suspended solids in the wastewater.

On the other hand, wastewater from the storage of fruits and vegetables, which often involves the cleaning and washing of produce before storage, typically consists of a mix of organic materials such as leftover fruit and vegetable residues. This wastewater may also contain potential residues of pesticides or chemicals used in agricultural practices. When processing oranges, a citrus fruit from the Rutaceae family, certain chemical compounds are generated during the process, which can have adverse effects on aquatic environments due to the presence of essential oil residues. The various compounds found in these essential oils can potentially have significant impacts on aquatic ecosystems.

Lastly but not least, wastewater generated during the tomato-to-ketchup processing will possess distinctive characteristics, primarily marked by its high organic content originating from tomato residues like peels and seeds, resulting in elevated biological and chemical oxygen demand. This wastewater may contain suspended solids as well as an acidic nature due to tomatoes' inherent acidity.

2.4 Agro-foods sector

The Soroti Industrial and Business Park is set to become a hub for the processing of a diverse range of agro-foods such as grains, cassava and honey processing, each destined for various valuable products. The grains in focus include cowpeas, simsim, rice, soybeans, sorghum, millet, maize and groundnuts.

2.4.1 Seed oils

The wastewater generated from seed oils will be from the processing of peanuts into oil. This wastewater will be characterized by a high organic load, including fats and oils, suspended solids, and elevated BOD and COD levels. It may contain nutrients, pesticides, and have variable pH and temperature. Emulsified oils generated within the wastewater may pose treatment challenges, and the wastewater may exhibit distinct colour and odour.

The solid waste from processing of seed oils includes shells, skins, meal, seed cake, these will be valorised into pellets which serve as animal feeds.

2.4.2 Cassava processing

The cassava processing sector will involve the manufacture of two main products; cassava starch and ethanol. In order to produce cassava starch, the roots are thoroughly cleaned, chopped, dried, ground and stored. In order to produce ethanol from cassava, there is preparation of the cassava, pulping, fermentation, distillation and dehydration. This report has been prepared based on the processing of 100 tons and 78 tons of cassava into starch and ethanol respectively. The water required in the cassava processing is mainly for cleaning of equipment and the peeled cassava. The wastewater generated from this process is composed of high organic and inorganic content including carbohydrates, sodium and potassium as well as cyanide.

2.4.3 Food/Grain

In the grain processing sector, sorghum processing into flour was considered. The quantity of grains to be considered were based on the findings of the sectoral analysis and assessment that is 1,930 tons of grains were considered to be processed into flour per day. The water required in the processing will mainly be required for cleaning of the grains as well as cleaning of the equipment. Wastewater generated from the processing of grains into flour has high amounts of suspended solids, organic matter leading to a high BOD and TSS.

2.4.4 Potato Puree

Sweet potatoes are often processed into purees that can be frozen, canned or packaged. The quantity of potatoes to be processed into puree was determined from the team sector analysis and quantification. In this report, a production capacity of 90.4 kg per day was considered.

Water is used in the filtration or straining to achieve the desired consistency. The wastewater produced is high in organic content and therefore has a high BOD concentration and TSS. The solid waste generated from the processing includes peelings and pulp.

2.5 Concrete sector

The expected concrete processes to be done at the industries within the industrial park include manufacture of concrete products. The main inputs into this process are aggregates and cement that are mixed to produce concrete of varying grades. The main stakeholders within this sector are Sanqua Engineering and Wodma Investment Ltd. The sector will rely on adequate water supply for mixing the aggregates and cement as well as curing of the cast concrete products. The sector must tackle the concrete waste generated during the process.

The quantity of aggregates and cement to be processed were based on the results from the final team sector analysis and quantification. This report has been prepared based on the processing of 101 tons of raw materials per day. The wastewater generated from this process has a high concentration of chemical pollutants as compared to the biological pollutants. The treatment of the wastewater generated from the concrete sector is important to avoid pollution of receiving water bodies. Additionally, given that the solid waste generated from this sector is non-biodegradable, it has to be handled with care so as to preserve the environment. The solid waste generated is mainly from unused concrete material both liquid and solid states.

Wastewater generated during concrete manufacturing will be a mixture of various contaminants, including suspended solids, dissolved solids, organic materials, and heavy metals. This wastewater will arise from activities such as equipment, truck, and mixer cleaning, aggregate washing, and sludge dewatering from sedimentation tanks. To manage concrete wastewater responsibly, the practices may involve minimizing wastewater generation through process optimization, spillage reduction, and water recycling. Segregating wastewater into high-strength and low-strength categories will help reduce the overall volume of wastewater generated.

2.6 Herbal medicine sector

The main stakeholder within this sector is Jena Herbal Pharmaceuticals which deals in the production of herbal medical products such as Covidex, Jena artemune, Jena flue herbal syrup, Jena diabetes, Jena malaria etc. The sector will rely on water mainly for the manufacture of these medicines. The main waste produced by the company includes filter media and residue, empty containers and packaging as well as laboratory waste.

Solid waste from the herbal medicine sector will comprise of hazardous waste, packaging waste, laboratory waste. It is proposed that the hazardous waste from this sector be disposed of by incineration and recycling of plastics from packaging be highly encouraged.

Wastewater from herbal medicine production will have varying pollutants. Its composition will depend on the processes and ingredients used and may contain organic compounds, solid residues, and diverse chemicals specific to the herbs involved. The nutrient content will vary based on the herbal materials used.

2.7 Fish sector

The wastewater produced during the processing of smoked fish will be rich in organic matter, stemming from fish scraps, skins, and oils, resulting in elevated biological oxygen demand (BOD) and chemical oxygen demand (COD). Additionally, the use of oils or fats in the smoking process will contribute to the presence of challenging-to-remove oil and grease components.
Some of the solid waste from the fish sector include the viscera, skins, heads, bones, fins. These will be valorised into pellets to serve as animal feeds.

The wastewater generated during the processing of fish into omega-3 oil will have high fat content, primarily comprising omega-3 oils and other lipids, resulting from the breakdown of fish. Some extraction methods may employ chemical solvents, introducing the need for their careful management. Organic matter released from the fish will add to the biological oxygen demand (BOD) of the wastewater. Additionally, nutrients such as nitrogen and phosphorus from the fish may be present.

2.8 Domestic Sector

The domestic wastewater was estimated based on an 80% water consumption return rate. A peak hour factor of 1.5 is applied to the estimated wastewater flow to cater for hourly fluctuations. Domestic demand quantifications were done for all the employees within the industrial park as well as the hotel sector. The domestic solid waste will be expected to be composed of organic waste like food wastes, plastics for example plastic bottles of beverages and paper.

3. Water Supply

3.1 Introduction

The existing and potential industries to be set up in the Soroti Industrial and Business Park require varying amounts of water for industrial processes, cleaning, utilisation by staff. The industries that are operational within the park currently rely on piped water supply, however, some industries like Sanqua have drilled boreholes to meet the water demand. This chapter describes the estimation of the water demand and the proposed water supply options. The opportunities for integrating the existing water supply infrastructure in Soroti municipality are also explored.

3.2 Existing Infrastructure

The water supply system within Soroti District is managed by National Water and Sewerage Corporation (NWSC). Water is abstracted from the Awoja river and undergoes conventional water treatment. The water is pumped to a reservoir tank in Soroti and supplies Soroti city, Kaberamaido town council (in Kaberamaido district), Kalaki town council and Otuboi (in Kalaki district).

The water treatment plant which is owned and efficiently operated by the National Water and Sewerage Corporation (NWSC) has a design capacity of 3,000 m^3/d. The current water treatment plant capacity utilisation based on National Water and Sewerage Corporation (NWSC) operational data is 93%. In addition, NWSC is currently implementing a project for expansion of the water treatment plant to 7,815 m^3/day in 2024. The expansion works will enable extension of water supply services to targeted satellite communities in Amuria and Soroti districts. The existing water supply system has three storage reservoirs; two 2,000 m^3 capacity and one 2,100 m^3 capacity located at the Soroti Rock.

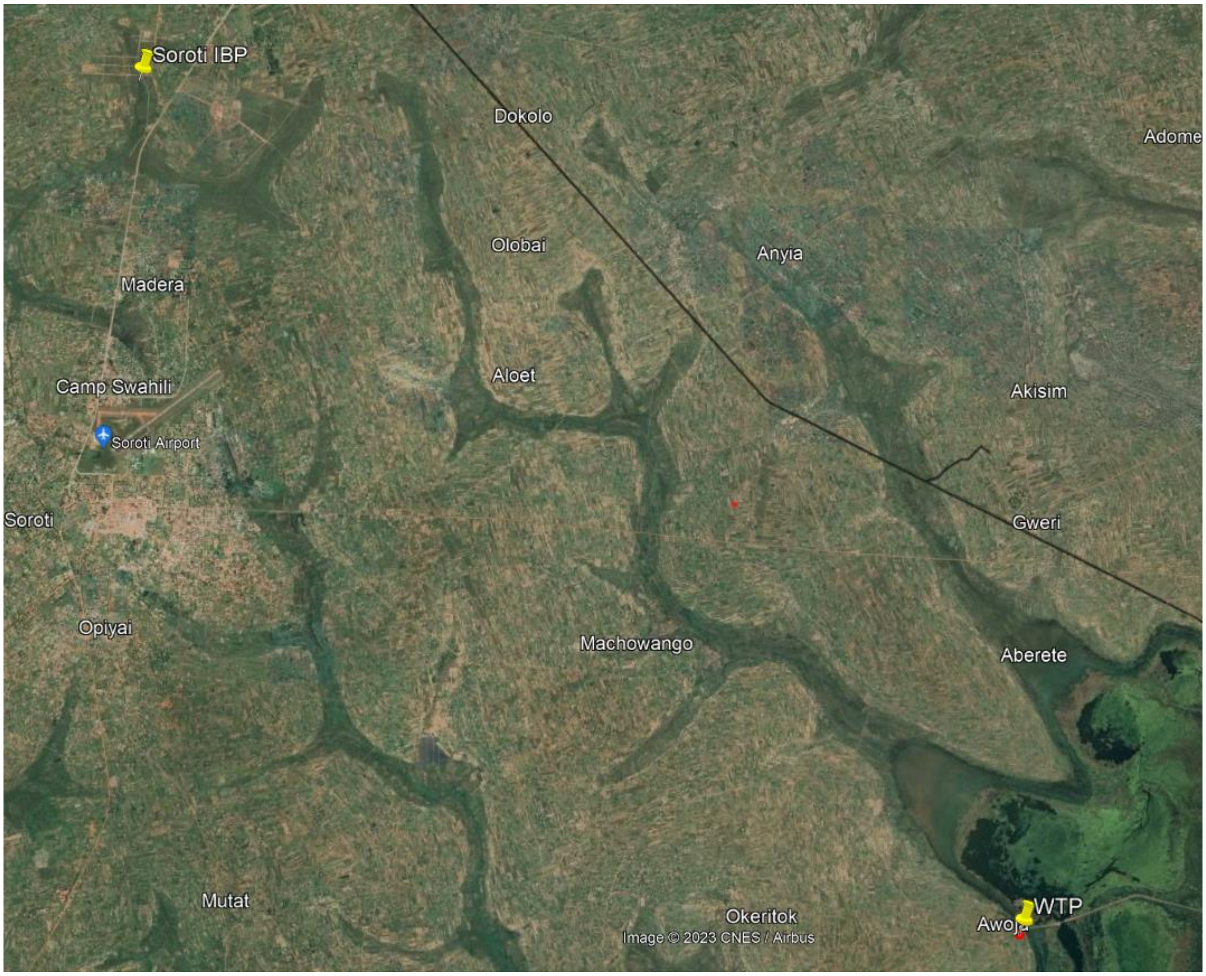

Figure 3-1: Location of the NWSC Awoja Water Works

The existing industries in the industrial park are served by the piped water supply system.

3.3 Water Demand Categories

The water demand categories comprise of:

i. Domestic demand: Water consumed by all the people expected at the Soroti Industrial Park. It also includes the water requirements for social infrastructure that include a hotel and hospital, a skilling centre, nursery, sports facility, and restaurant

ii. Industrial demand: Water required to support the sectors and processing plants in the Soroti Industrial Park. This demand includes firefighting and cleaning water requirements.

3.4 Design Criteria

3.4.1 Domestic Demand

The per capita water consumption has been determined based on the Directorate of Water Development (DWD) Water Supply Design Manual 2nd Edition (Environment, 2013). The domestic water consumption per capita is 50 to 100 litres per capita per day.

3.4.2 Industrial Demand

The industrial demand for different existing and potential sectors at the Soroti Industrial Park has been assessed based on the total quantity of raw materials that will be processed. The water requirements for each sector are presented in the subsequent sections.

3.4.2.1 Dairy Sector

A range of products under the dairy sector have been considered; cheese, yoghurt, powdered milk, UHT milk, ice-cream and ghee, and water requirements for each estimated as described below. In the dairy industry, water serves as a versatile and indispensable resource, facilitating various stages of production for cheese, yogurt, UHT milk, powdered milk, and ghee. It plays a pivotal role in processes like pasteurization to ensure safety, curds formation in cheese production, and fermentation in yogurt making. Water is also essential for maintaining cleanliness through equipment cleaning and sanitation. Its use extends to heating and cooling in UHT milk production. The water requirement for production of the different dairy products has been determined considering 10,000 litres, 8,000 litres and 4,000 litres of raw milk for the bulking and cooling, yoghurt and ice-cream production respectively as shown in Error! Reference source not found..

Table 3-1: Water requirement for production of different dairy products

Dairy product	Water requirement (m^3/s)
Yoghurt	32.2
Bulking and cooling	15.0 – 20.0
Ice cream	6.9 – 13.8

3.4.2.2 Fruit and vegetable sector - washing and packaging, and processing.

Water requirement have been estimated for different fruit and vegetable types to be processed by the existing and potential industries in the Soroti Industrial Park.

The amount and quality of water required in the process of fruit and vegetable sorting, washing and packaging depend on several factors, such as the type and condition of the raw material, the processing method and equipment, the hygiene standards and regulations, and the environmental conditions. The amount of water required in washing and packaging one ton of fruits on the study carried out on water consumption in fresh-cut fruit and vegetable production as $2.4m^3$ to $11.0m^3$ and $5.0m^3$ to $16.0m^3$ respectively (Lehto *et al.*, 2014). According to discussions held with the Value Chain Expert, a total 800 tons of fruits are harvested in a season of 3 months. Half of this (400 tons) is sold elsewhere, 200 tons are sold to fruit processing companies while the remaining 200 tons are available for storage. Assuming an equal quantity of fruits to be brought in to the storage facility per day, 3 tons of fruits shall be expected for storage per day which totals its water requirement to $7.2m^3$ to $33.0m^3$.
washed

Water plays a crucial role in the industrial-scale processing of fruits to produce both ready-to-drink juice and juice concentrate. Water is mainly required for equipment sanitation, cooling systems, and steam generation, dilution of the concentrated fruit puree to achieve the desired taste and consistency for RTD fruit juice. Water requirement to process 39.8 tonnes of tomatoes to tomato ketchup has been estimated as 339 m^3/s. The amount of water required to process mangoes and oranges for both fruit puree and RTD juice has been determined for 320 tonnes of each of the raw fruits as shown in Error! Reference source not found..

Table 3-2: Water requirements to produce different juice types from fruits

Fruit types	Water requirement (m^3/s)	
	Fruit puree	Ready-to-drink juice
Mangoes	448.0 – 2,006.0	568.0
Oranges	448.0 – 2,006.0	318.0

3.4.2.3 Fish sector

In a smoked fish processing industry, water is required for different purposes including the initial washing of fish, soaking fish in brine solution, cooling and cleaning the equipment used to maintain hygiene and quality standards. The water requirement for smoked fish processing has been estimated for one tonne of raw fish expected to be processed daily at the Soroti BIP in the range of 1.10 m^3 to 2.20 m^3. Water requirement has also been estimated for fish processing to omega 3 oil 19.2 tonnes of fish per day as 288.0 m^3 to 326.4 m^3. However, this has not been included in the final quantifications of the final water requirements for the Soroti BIP.

3.4.2.4 Seed oil sector

The water requirement for the seed oil sector has been estimated for peanuts from which the oil will be extracted. Goldseed International Limited and Asalalamaal are the two companies that will be dealing in the seed oil sector. The water demand for this sector has been estimated based on the expected capacity of seed oil production of 178.6 tonnes of peanuts in the range of 8.93 m^3 to 35.72 m^3.

3.4.2.5 Concrete sector

In the concrete production process at a batching industry, water is needed primarily to mix with cement, aggregates, and other components. It helps bind these materials together to create a mouldable mixture that can be shaped into various concrete products, such as blocks and pavers. Additionally, water is used to clean equipment and maintain a clean production environment. Water is also essential for curing the finished concrete products, ensuring they remain moist during the early stages of setting to achieve the desired strength and durability. The water requirement for producing one tonne of concrete products is in the range of 0.3 - 0.4 m^3 as per the industrial practices. According to the interviews conducted with Sanqua, the amount of water used per day to produce 20 tonnes of concrete products is 0.65 m^3. The water requirement for the concrete sector has been estimated based on the expected capacity of 101 tonnes of concrete products at the park. This would require 30.3 m^3 to 40.4 m^3 of water according to the industrial practices.

3.4.2.6 Pharma/herbal sector.

When crafting herbal medicine from herbs, water is an essential ingredient used in various ways. It is often employed as a solvent to extract the beneficial compounds from the herbs. This extraction process allows the herbs to release their medicinal properties into the water. The resulting herbal infusion can then be used as a base for herbal teas, syrups, or other remedies. Water also serves as a medium for dilution, blending, and formulating herbal preparations. Additionally, it is necessary for maintaining cleanliness and hygiene during the herbal medicine-making process, ensuring the safety and quality of the final products. According to an interview with Mr David from Jenna Herbals, the company purchases essential oils from local producers. Water is only required in cleaning the equipment and machines, dilution, and distillation to obtain medicine. Considering a production capacity of 5 tonnes per day that is planned for by Jenna Herbals, the water requirement for this sector was estimated as 25 m^3 to 500 m^3/day

3.4.2.7 Cassava processing

The amount of water required in cassava processing is for cleaning of the peeled cassava as well as cleaning of the equipment. This water demand in a cassava industry largely depends on the required cassava products. Production of starch and ethanol from cassava has been considered for the Soroti Business and Industrial Park. The water requirement for the cassava sector has been estimated for expected 78 tonnes of cassava for ethanol and 100 tonnes of cassava for starch production. The estimated quantity of water is 312.0 m^3 to 1,950 m^3 and 760.0 m^3 and 950 m^3 for ethanol and starch production respectively.

3.4.2.8 Potato puree

The production of sweet potato puree involves several key processes starting with harvesting, followed by washing, peeling, cooking, mashing, and filtration. Water is required primarily in the washing, cooking, and mashing stages to facilitate the cleaning, softening, and processing of the sweet potatoes. Additionally, water may be used in the filtration or straining step to achieve the desired consistency in the puree. The water demand for the production of potato puree from potatoes has been estimated based on the values by the Value Chain expert as 0.33 m^3 to process 90.4 kilograms of raw potatoes.

3.4.2.9 Food/grains sector

Water is essential for various stages of grain processing, such as cleaning, milling, washing, and packaging. The water requirements are influenced by several factors, including the specific grain type, the processing method, equipment used, and environmental conditions. The average water demand for the grains sector has been estimated for 1,930 tonnes of grains that are expected at the Soroti BIP in the range of 386.0 m^3 to 7,720.0 m^3.

3.4.3 Peak Factors

The average day demand is determined from the summation of the domestic demand and industrial demand. The average day demand is subject to variations in the water demand such as seasonal availability of the quantity of raw materials. The maximum day demand factor of 1.3 is applied to the average day demand. The maximum day demand is used in the design of the storage reservoirs.

There are hourly fluctuations in demand over the duration of the day. The fluctuations are catered for by peak hour factors which are applied to the maximum day demand. The peak hour factor of 2.0 is adopted for the design of the distribution main supplying the Soroti Industrial Park.

3.5 Water Demand Estimation

3.5.1 Domestic Demand

The per capita water consumption is estimated within the range of 50 to 100 litres per capita per day. The estimate or the number of workers per factory were based on outcomes of the stakeholder engagement with the respective industries that are already operational. Furthermore, for the factories that are yet to be set up, estimates of the number of workers were projected based on the data obtained from the existing industries. The estimated total number of people per sector at the Soroti Industrial Park has been estimated as 3,250 as shown in Error! Reference source not found.. The domestic water demand for each sector has been computed as shown in Error! Reference source not found.. Using the upper limit of the per capita water consumption, the computed domestic water demand for the Soroti Industrial Park is 325.0 m^3/d.

Table 3-3: Number of people expected at the Soroti Industrial Park for different sectors.

Sector	Expected number of people
Mango	500
Orange	500
Tomato ketchup	100
Smoked fish	50
Pharma/Herbals	50
Potato puree	50
Fruit storage	50
Milk bulking and cooling	100
Yoghurt	150
Ice-cream	100
Peanuts	200
Food/Grain	1000
Ethanol production	100
Starch production	150
Concrete	150
Total	**3250**

Table 3-4: Domestic demand for each industry in Soroti Industrial Park

Sector	Percentage Development of Soroti BIP		
	35%	75%	100%
Minimum Water Requirement (m^3/day)	56.88	121.88	162.50
Mean Water Requirement (m^3/day)	85.31	182.81	243.75
Maximum Water Requirement (m^3/day)	113.75	243.75	325.00

3.5.2 Industrial Demand

The realistic time frames for the gradual development of an industry must be considered when determining the industry's water demand. In this study, progressive development has been considered as a percentage of full capacity for each potential sector. The water demand has been estimated at the 35%, 75% and 100% of full capacity of each sector.

Error! Reference source not found. shows the total industrial water demand for each sector that will be included at the park by different industries.

Table 3-5: Industrial water demand for all the sectors at the Soroti Business Industrial Park.

Sector	Water Requirement (m3)	Percentage Development of Soroti BIP		
		35%	75%	100%
Sweet potato puree	Minimum Water Requirement	0.12	0.25	0.33
	Mean Water Requirement	0.12	0.25	0.33

Sector	Water Requirement (m3)	Percentage Development of Soroti BIP		
		35%	75%	100%
	Maximum Water Requirement	0.12	0.25	0.33
Dairy bulking and cooling	Minimum Water Requirement	5.25	11.25	15.00
	Mean Water Requirement	6.13	13.13	17.50
	Maximum Water Requirement	7.00	15.00	20.00
Food/grain	Minimum Water Requirement	135.10	289.50	386.00
	Mean Water Requirement	1418.55	3039.75	4053.00
	Maximum Water Requirement	2702.00	5790.00	7720.00
Herbal Medicine	Minimum Water Requirement	8.75	18.75	25.00
	Mean Water Requirement	91.88	196.88	262.50
	Maximum Water Requirement	175.00	375.00	500.00
Smoked fish	Minimum Water Requirement	0.39	0.83	1.10
	Mean Water Requirement	0.58	1.24	1.65
	Maximum Water Requirement	0.77	1.65	2.20
Concrete	Minimum Water Requirement	10.61	22.73	30.30
	Mean Water Requirement	12.37	26.51	35.35
	Maximum Water Requirement	14.14	30.30	40.40
Peanut oil	Minimum Water Requirement	3.13	6.70	8.93
	Mean Water Requirement	7.81	16.74	22.33
	Maximum Water Requirement	12.50	26.79	35.72
Cassava - Ethanol	Minimum Water Requirement	109.20	234.00	312.00
	Mean Water Requirement	395.85	848.25	1131.00
	Maximum Water Requirement	682.50	1462.50	1950.00
Cassava - Starch	Minimum Water Requirement	266.00	570.00	760.00
	Mean Water Requirement	299.25	641.25	855.00
	Maximum Water Requirement	332.50	712.50	950.00
Tomato Ketchup	Minimum Water Requirement	118.68	254.32	339.10
	Mean Water Requirement	118.68	254.32	339.10
	Maximum Water Requirement	118.68	254.32	339.10
Fruit storage	Minimum Water Requirement	2.52	5.40	7.20
	Mean Water Requirement	7.04	15.08	20.10
	Maximum Water Requirement	11.55	24.75	33.00
Orange (Concentrate)	Minimum Water Requirement	156.80	336.00	448.00
	Mean Water Requirement	429.52	920.40	1227.20
	Maximum Water Requirement	702.24	1504.80	2006.40
Mango (Concentrate)	Minimum Water Requirement	156.80	336.00	448.00
	Mean Water Requirement	429.52	920.40	1227.20
	Maximum Water Requirement	702.24	1504.80	2006.40
Oranges (RTD)	Minimum Water Requirement	111.33	238.56	318.08
	Mean Water Requirement	111.33	238.56	318.08
	Maximum Water Requirement	111.33	238.56	318.08
	Minimum Water Requirement	198.80	426.00	568.00

Sector	Water Requirement (m3)	Percentage Development of Soroti BIP		
		35%	75%	100%
Mangoes (RTD)	Mean Water Requirement	198.80	426.00	568.00
	Maximum Water Requirement	198.80	426.00	568.00
Total (Industrial)	**Minimum Water Requirement**	**1,283.5**	**2,750.3**	**3,667.0**
	Mean Water Requirement	**3,527.4**	**7,558.7**	**10,078.3**
	Maximum Water Requirement	**5,771.4**	**12,367.2**	**16,489.6**

The total industrial water demand considering 100% development of the Soroti Industrial Park ranges from 3,667 m^3/day to 16,490 m^3/day.

3.5.3 Average day demand at the Soroti Industrial Park

The average day demand at the Soroti Industrial Park, inclusive of the domestic and industrial water demand is shown in Error! Reference source not found..

Table 3-6: Average day demand

Parameters	Percentage Development of Soroti BIP		
	35%	75%	100%
Minimum Water Requirement (m^3/day)	1,340.34	2,872.15	3,829.54
Mean Water Requirement (m^3/day)	3,612.73	7,741.56	10,322.08
Maximum Water Requirement (m^3/day)	5,885.12	12,610.97	16,814.63

The maximum day demand at the Soroti Industrial Park has been obtained as 21,859m^3/day by increasing the maximum water requirement at 100% development of the Soroti Industrial Park by the maximum day demand factor of 1.3. According to the Water Supply Design Manual 2nd Edition by the Ministry of Water and Environment, the industrial water demand is estimated based on the area occupied by the industry. This results into a maximum day demand of 4,612 m3/day at 100% development capacity based on 219 acres of the park. However, the sectoral approach that was used in this study takes into consideration the intensity of the industries and the varying water requirements for the different industrial processes. The water demand estimation was done specific to water requirements of the different processes presented above for the various sectors considered for Soroti BIP.

3.5.4 Firefighting water demand

Fire hydrants in an industrial park will be placed in proximity of the industries along the main access roads, where they can easily be accessed by fire trucks. Since firefighting water is regarded as Non-Revenue Water (forms part of the unbilled authorized consumption), the fire hydrants should be secure from commercial water sellers who may misuse the hydrants by getting water free of charge. According to the Water Supply Manual MWE (2013), the firefighting water demand is estimated according to the area on land occupied by the industry. Soroti Industrial Park occupies 217 acres of land, and its firefighting water demand has been estimated at a rate of 6,480 m^3/d for two hours. Fire hydrants shall be connected to DN400 mm transmission lines. The DN400 mm pipeline shall supply water to both the storage tank for use within the Soroti Industrial Park and the hydrant for use during firefighting operations. The fire hydrants shall be provided to ensure that their clearance around its circumference is up to 4.7m for easy connection of the hose pipe. The spacing between the hydrants shall be maintained in the range of 61m to 91m[1].

3.6 Water Supply Options

3.6.1 Boreholes (Production Wells)

The industrial park is located in Akweng catchment in the Lake Kyoga Basin. The estimated exploitable groundwater in the entire catchment is 26.8Mm^3/year (Agency, 2011). The estimated exploitable groundwater in the industrial park is 22.70 m^3/day (based on 0.88 km^2 acreage).

The water demand estimation for the industrial park is a minimum of 21,859 m^3/day. The available groundwater can meet 0.1% of the estimated water demand for the industrial park. It should therefore be noted that ground water is not a viable option for the Soroti Industrial Park Furthermore, the estimated water demand that is specified in this report (21,859 m^3/d) excludes that water demand for Soroti water supply service area that is being served by the existing NWSC water supply system.

3.6.2 Extension of existing water supply system

The existing water supply system is undergoing expansion to increase the current capacity by 161%. While NWSC has earmarked areas of densification of the existing water supply system, the option of extension of this system would provide a short-term solution to meet the water demand in the industrial park. If the existing water supply system is expanded to the capacity of 7,815 m^3/day, according the works that are currently underway, the initial water demand for the industrial park (35% development) can be met by the rehabilitated and expanded NWSC water supply system. However, considering the rapid population growth and increasing domestic water demand requirements in the NWSC Soroti water supply service area that extends to Kaberamaido District, the water supply system will not be able to meet the parks water demand at 35%, 75% and 100% full capacity. The consultant therefore recommends construction of an independent water treatment plant, transmission mains, reservoirs and distribution system for the Soroti Industrial Park at full operational capacity.

The timeline for the full development and operation of the industrial park is not known. However, the supply from NWSC can meet part of the water demand at 35% of the industrial park's development.

3.6.3 Surface water supply

The Consultant explored the possibility of constructing an independent water system for supply to the industrial park. The nearest surface water source is the Awoja river, located approximately 22km away from the industrial park. The surface water supply option would require construction of an intake on the Awoja river, a water treatment plant of at least 17,000 m^3/day capacity, storage reservoir and water transmission pipelines. However, this option is capital intensive. Therefore, the consultant proposes that a smaller water treatment plant of capacity 9,000 m^3/day be constructed in the medium term to meet the water requirements at the Soroti BIP. The constructed water supply system shall meet the water requirement at the park at 35% of full park capacity and part of the water demand at 75% capacity of the park. The construction of this water supply system would reduce the stress on the existing water system for the Soroti district and the satellite towns it supplies. The long-term water demand at full capacity of the park shall be met by expanding the newly constructed plant of capacity 9,000 m^3/day by a capacity of 8,000 m^3/day.

[1] How Far Apart Do Fire Hydrants Have to Be UPDATED 2023 ♡ (fire-extinguisher-guide.com)

Previous water availability studies for Awoja catchment indicate low and mean stream flows of approximately 2 m^3/s and 4.5 m^3/s respectively (172,800 m^3/d – 1,166,400 m^3/d) (NELSAP 2012). Based on this earlier study, the proposed surface water resource is adequate to meet the estimated demand for the industrial park. However, the consultant recommends that a more detailed water resources assessment is undertaken at feasibility and detailed design stage of the project to confirm that water availability at the proposed abstraction site at Awoja Bridge, near the existing NWSC water treatment plant on Kumi-Soroti road. The proposed study should utilise the most recent Awoja river flow discharge data and also take into consideration the emerging impacts of climate and land use changes within the Awoja catchment

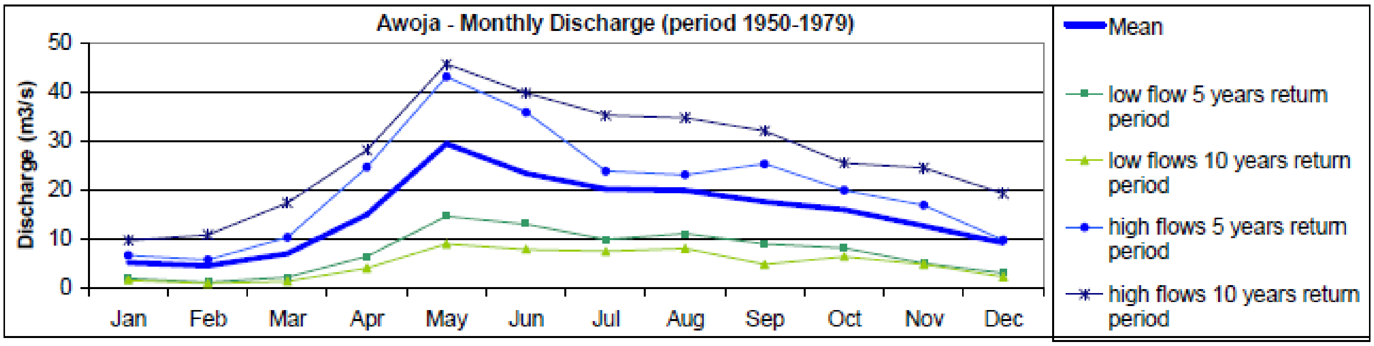

Figure 2: Simulated discharge for Awoja catchment for the period 1950-1979 (NELSAP 2012)

The water availability assessment shall take into consideration existing upstream and down stream users. Additional potential issues that will be studied in detail at feasibility and detailed design includewater quality and ground water availability within the Soroti Industrial park..

3.7 Water Storage

3.7.1 Design Criteria

A storage reservoir is required to provide for fluctuations in water demand during the day (e.g., the hourly peak flow) and minimize disruptions in flow during periods of maintenance. Furthermore, the storage provides for a constant residual pressure and flow for smooth operations at the Soroti Industrial Park.

The DWD Water Supply Design Manual recommends 30% of the maximum day demand has been adopted for storage.

3.7.2 Calculated Storage

The storage requirement has been estimated based on the maximum day demand for 100% production capacity at the Soroti Industrial Park. The calculated storage is shown in Error! Reference source not found..

Table 3-7: Calculated Water Storage

Water Requirement	Maximum Day Demand (m^3/day)	Calculated Storage Capacity(m^3/day)	Adopted Storage Capacity (m^3/day)
Minimum Water Requirement	4978.4	1,494	1500
Mean Water Requirement	13418.7	4,026	4100
Maximum Water Requirement	21859.0	6,558	6600

The adopted storage reservoirs range in capacity from 1,500 m^3 to 6,600 m^3. The duration of the storage provided by the proposed reservoir tanks over the development of the Soroti Industrial Park are shown in Error! Reference source not found..

Table 3-8: Duration of Storage

Parameters	Percentage Development of Soroti BIP			
	35%	**75%**	**100%**	**110%**
Minimum Water Requirement (m^3/day)	1340.3	2872.2	3829.5	4212.5
Adopted Storage Capacity (m^3)	1500	1500	1500	1650
Storage Capacity (%)	112%	52%	39%	39%
Hours of Storage (hour)	**27**	**13**	**9**	**9**
Mean Water Requirement (m^3/day)	3612.7	7741.6	10322.1	11354.3
Adopted Storage Capacity (m^3)	4100	4100	4100	4510
Storage Capacity (%)	113%	53%	40%	40%
Hours of Storage (hour)	**27**	**13**	**10**	**10**
Maximum Water Requirement (m^3/day)	5885.1	12611.0	16814.6	18496.1
Adopted Storage Capacity (m^3)	6600	6600	6600	7260
Storage Capacity (%)	112%	52%	39%	39%
Hours of Storage (hour)	**27**	**13**	**9**	**9**

The duration of storage provided at 100% development of the Soroti Industrial Park is 9 to 10 hours. This is deemed sufficient storage to cater for disruption in supply due to maintenance works. The storage requirement has also been estimated at 110% of the full capacity of the park as 9 to 10 hours. The increment considered serves to cater for any uncertainties in the water storage and requirements, and it is considered sufficient to cater for any disruptions.

3.7.3 Storage Reservoirs

The storage capacity for the industrial park has been estimated in the preceding sections. The proposed reservoir type is the pressed steel reservoir tanks: The tanks are configured to provide storage from as low as 1.5m^3. The tanks can be erected on reinforced concrete dwarf walls or steel towers

The land within the industrial park is fairly flat, and as such the storage reservoirs have to elevated to provide sufficient residual head. The Consultant proposes that the storage reservoirs for the industrial park should be constructed at Soroti rock, where the existing storage reservoirs are located. This will provide for sufficient residual pressure within the industrial park and the additional storage for supply to the local community.


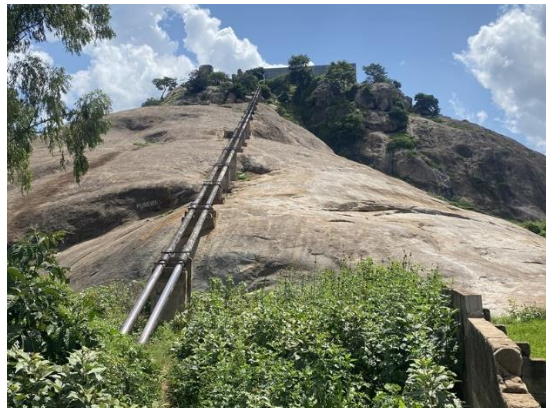

Figure 3-3: Existing Storage Tank Location in Soroti

The proposed minimum storage capacity can be met by providing at least 6 reservoir tanks of 1,225 m^3 capacity. The reservoirs can be erected on reinforced concrete dwarf walls. This capacity shall be confirmed during feasibility and detailed design stage of the water and sanitation infrastructure.

During the detailed engineering design, the pressure required at the water consumption ends shall be analysed. Pumps are proposed to boost the water pressure supplied to the park. The consultant proposes that these pumps be operated by hydroelectric power, and a standby source of power from solar energy is proposed as opposed to diesel generators. This is intended to reduce the carbon dioxide emission from diesel generators. The total quantity of carbon dioxide emission will be determined during the detailed engineering design when the pump specifications and power requirements have been computed. However, it can be noted that for every litre of fuel, 2.62kg of carbon dioxide are produced[2]. The water pumps will also provide the required water pressure for the fire hydrants.

3.7.4 Operation and Maintenance

The operation and maintenance of the water supply infrastructure at Soroti industrial park based on the short-term solution of extension of NWSC will comprise of the following:

i. Payment of water bills. NWSC will provide water bills based on the water consumed per month. The water bills will be paid on a monthly basis.
ii. Desilting of the storage reservoirs. The accumulation of silt is dependent on the water quality from the supply main. The desilting can be carried out every two years.
iii. Routine maintenance works. The routine maintenance works will be determined based on a visual assessment of the infrastructure. This includes works such as replacement of valves, painting of steel tower and repair of leakages of pipes and/or tanks.

The operation and maintenance of the water supply infrastructure at Soroti industrial park based on the long-term solution of construction of a new water supply system will be similar to the list above. The operation and maintenance of the water supply system (intake, water treatment plant, transmission pipelines, etc) will be carried out by NWSC, which has the mandate of providing water supply and sewerage services in Urban Areas. The management of the Soroti Industrial Park will only focus on regularly cleaning of storage tanks within the industrial park, testing and checking of fire hydrants, and repair of distribution pipelines within the boundary of the industrial park.

[2] How To Calculate Emissions from Diesel Generator? - UtilitySmarts

4. Wastewater Management

The industries that have been allocated land within the Soroti Industrial and Business Park will require varying amounts of water for industrial processes, cleaning, domestic use, etc. This chapter will detail the estimation of the wastewater flows and pollution load. The opportunities for integrating the existing wastewater supply infrastructure in Soroti city are also explored.

The design criteria for wastewater management includes determining flow rates and wastewater characteristics, selecting treatment processes, designing layout and infrastructure, managing sludge, ensuring regulatory compliance, and considering energy efficiency and future expansion.

4.1 Existing Infrastructure

4.1.1 Existing Wastewater Management Facilities in Soroti Industrial Park

The Soroti Industrial and Business Park currently does not have a sewer network sewered.. In the development of the industrial park, the consultant shall propose shared infrastructure to manage the wastewater produced from the park.

There is a wastewater treatment plant within the site of the Soroti fruit factory which treats the factory wastewater before it is released to the environment. However, the WWTP is overwhelmed and cannot treat the wastewater to the required standards. According to the officials from the Soroti Fruit Factory, tests were conducted on the wastewater and the results indicated that the BOD and COD content of the wastewater were 300mg/l and 700mg/l respectively. This is extremely higher than the minimum allowable levels prescribed by NEMA. The Soroti fruit factory administration informed us that they currently lack any documentation concerning the existing WWTP design. However, based on our visit and our previous technical experience, the consultant attributes the elevated effluent contamination levels might be attributed to an inadequately designed system that fails to meet the influent demands. Furthermore, it's possible that the concentration levels result from the WWTP solely performing sedimentation and filtration without additional treatment.

Figure 4-1: The wastewater treatment plant at Soroti Fruit Factory

4.1.2 Existing Wastewater Management Facilities in Soroti City

Soroti city has existing Waste Stabilization Ponds (WSP) under the management of NWSC.

Figure 4-2: Location of the NWSC WSPs

The existing WSP treat sewered domestic wastewater from the centre of Soroti town and faecal sludge from septic tanks and pit latrines. The WSP treats approximately 10,000 m^3/day of wastewater. The reserve capacity at the WSP is limited due to demand from the large unsewered catchment.

4.2 Design Criteria

4.2.1 Domestic Wastewater

The domestic wastewater comprises of wastewater from toilets, bathrooms and kitchens. The domestic wastewater was estimated based on an 80% water consumption return rate. A peak hour factor of 1.5 is applied to the estimated wastewater flow to cater for hourly fluctuations.

The domestic wastewater characterisation is shown in Error! Reference source not found..

Table 4-1: Domestic Wastewater Characterization

Parameter	Lower Limit	Upper Limit
BOD (mg/L)	155	286
TSS (mg/L)	155	330
TN (mg/L)	26	75
TP (mg/L)	6	12
NH3 (mg/L)	4	13
Coliform Bacteria	10	100
Faecal Coliforms	10	100

4.2.2 Industrial Wastewater

4.2.2.1 Dairy Sector

Wastewater from the dairy sector contains high levels of organic matter, nutrients, salts, and pathogens that can pollute water resources and pose health risks. Wastewater from the dairy sector comes from various sources, such as washing of the equipment, milk losses, staff activities, and whey separation.

The following subsectors had been considered under the dairy sector;

i) Cheese
ii) Yoghurt
iii) Powdered Milk
iv) Ghee
v) Ice-cream

The process of production of the milk products results in liquid waste in the form of whey, wastewater and ghee residue. The whey can be stored and valorised as animal feeds and protein supplement while the ghee residue can be used for fat extraction or wasted. To extract fat from ghee residue, the residue is dissolved in hot water, followed by filtration and centrifugation. This allows the separation of fat, which can be reused in cream or melted butter. Error! Reference source not found. shows the characterisation of wastewater from the dairy industry during production of milk products from 8000 litres of raw milk for yoghurt production and 4,000 litres of raw milk for ice cream production. According to Hanková et al., 2020, the volume of wastewater generated during the production of cheese from 1000 litres of milk is 1.8m^3.

Table 4-2: Dairy Sector wastewater characterization

Parameter	Cheese Sector		Yoghurt Sector		Powdered milk Sector		Ice cream Sector		Ghee Sector	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
BOD (mg/L)	590	6,000	500	2,000	1,500	1,500	1200	4000	2,300	2,300
COD (mg/L)	1,000	63,300	6,500	6,500	3,000	3,000	1150	9200	3,795	3,795
FOG (mg/L)	330	2,600								
TSS	190	2,500	200	1,000	100	1,550	340	1730	870	870
TN	18	830	20	80	250	250	14	272		
TP	5	280	5	20	20	20				
TS	1,920	53,200	1,000	5,000						

Regrettably, the Dairy Development Authority, which is a government agency scheduled to be a part of the park and intended to operate in the area designated for SMEs, had to limit its involvement to milk bulking and cooling as well as ice cream and yoghurt production. This decision was influenced by the substantial wastewater effluent concentrations and quantities along with the significant energy demands associated with the previously identified subsectors. Consequently, the analysis and consideration were narrowed down to only these sub sectors.

Wastewater generated from milk bulking and cooling operations is characterized by its high organic load, nutrient content (particularly nitrogen and phosphorus), typically lower pH, variable temperature, elevated biological oxygen demand (BOD), suspended solids, oil and grease. The specific characteristics can vary depending on the source of milk and processing methods (Farmers Journal, 2022). **Error! Reference source not found.** shows the characterisation of wastewater from the dairy industry during milk bulking and cooling. According to (ClearFox, 2023) the volume of wastewater generated during the dairy milk bulking and cooling of 10,000 litres is 20m^3.

Table 4-3 Dairy milk wastewater characterization.

Parameter	Lower Limit	Upper Limit
BOD (mg/L)	500	6000
COD (mg/L)	900	9000
TSS	100	800
TN	10	200
TP	10	100
Oil & grease	2	8

4.2.2.2 Concrete Sector

The concrete sector produces wastewater that contains high levels of chemical oxygen demand (COD) and suspended solids. The wastewater is generated from various processes such as mixing of aggregates with cement and curing of cast concrete.

According to Klus et al., 2017, the pollutant concentration in wastewater generated from the concrete manufacture process depends on the nature of concrete produced; the concentration is higher in pre-stressed concrete and reinforced concrete as compared to plain concrete. The summary of the characterisation is shown in Error! Reference source not found..

Table 4-4: Concrete Sector Wastewater Characterisation

Parameter	Lower Limit	Upper Limit
BOD (mg/L)	0	0
COD (mg/L)	510	510
TSS	475	475
TN	1.33	1.33

4.2.2.3 Agro-foods Sector

The wastewater generated from the Agro-foods sector contains high organic content leading to high BOD and COD levels. Its composition varies according to environmental factors and the knowledge of these physicochemical characteristics is essential to determine its future applications.

According to (de Oliveira Schmidt et al., 2022), the characterization of wastewater differs depending on the final product as shown in Error! Reference source not found. below.

The characterization was subsequently divided into distinct categories, namely, sorghum processing for beer, processing of food grains, processing of sweet potatoes for puree and the production of seed oils. This division was prompted by the elevated concentrations of wastewater generated during the processing of various Agro-foods, as listed in **Error! Reference source not found.**. Consequently, a decision was made to quantify the wastewater parameters exclusively for pre-existing industries and those presently in the construction phase. This choice is the reason for the focused analysis of companies engaged in, processing of sweet potatoes for puree, seed oils processing specifically for the peanut processing into peanuts oil, cassava processing into ethanol and starch and processing of the processing of food grains.
The food grain that was chosen as a representative sample was sorghum because it had the highest water requirement and ultimately would result in the highest wastewater generated.

Table 4-5: Wastewater characterization for the Agro-foods sector

	Peas		Simsim		Rice		Soybean		Sorghum		Millet		Maize		Groundnuts		Honey		Cassava Flour		Cassava Starch	
BOD (mg/L)	500	3,000	500	2,000	50	1,000	3,500	21,000	5,000	2,525	200	1,000	9,000	9,000	500	2,000	140	160	8,000	12,200	1,450	8,000
COD (mg/L)	1,000	6,000	1,000	4,000	1,000	2,000	5,000	30,000	10,000	5,500	400	2,000	11,500	11,500	1,000	4,000	-	-	15,700	62,000	2,000	14,700
FOG (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TSS	100	500	100	1,000	100	500	300	6,000	1,000	550	100	500	3,500	3,500	100	1,000	50	150	7	5,800	6,020	14,340
TDS																						
TN	10	100	10	250	10	50	50	500	500	275	40	150	250	250	10	250	5	10	360	1,730	20	530
TP	-	-	-	-	2	10	100	1,000	100	55	-	-	3,750	3,750	-	-	0	2	40	700	20	90
Cl																	-	-				
Zn																			1	5	1	5
Fe																			1	110	1	110
NH_3																						
TIC																						
Colour																						
Oil and Grease	50	200	50	500			100	5,000	500	275	50	200	200	200	50	500						
TS													19,700	19,700								
CN																			12	90	2	23
Na																			12	90	126	460
K																			350	5,900	350	5,900

Table 4-6 Wastewater characterization from Peanut oil

Parameter	Peanut oil		Cassava Flour		Cassava Starch		Food grains		Potato puree
BOD (mg/L)	500	2000	8,000	12,200	1,450	8,000	5,000	2,525	1,200
COD (mg/L)	1000	4000	15,700	62,000	2,000	14,700	10,000	5,500	2,400
FOG (mg/L)	50	500	-	-	-	-	500	275	
TSS	100	1000	7	5,800	6,020	14,340	1,000	550	600
TDS									
TN	10	250	360	1,730	20	530	500	275	1100
TP			40	700	20	90	100	55	120
Cl									
Zn			1	5	1	5			
Fe			1	110	1	110			
CN			12	90	2	23			
Na			12	90	126	460			
K			350	5,900	350	5,900			

4.2.2.4 Fruits and Vegetables

Wastewater generated from fruit processing of mangoes and oranges for concentrate and puree respectively typically exhibits a high organic load, containing sugars, organic acids, and fruit pulp residues. It can also contain solid particles like fruit peels, seeds, and residual pulp, contributing to suspended solids. The pH of this wastewater varies but is generally slightly acidic due to the natural acidity of fruits. Nutrient content, particularly nitrogen and phosphorus, is often high, potentially promoting eutrophication in receiving waters if not properly treated. Additionally, colour pigments and aroma compounds may be present, impacting the appearance and odour of the wastewater. High biological oxygen demand (BOD) is a concern due to the substantial organic matter. **Error! Reference source not found.** shows Wastewater characterization for Concentrate production.

Table 4-7 Wastewater characterization for Concentrate production

Parameter	Mango puree		Orange Concentrate	
BOD (mg/L)	400	1700	400	1700
COD (mg/L)	4400	5900	4400	5900
TS	4600	18900	4600	18900
TN	68	92	68	92
TP	13	19	13	19
E.Coli	3.1	3.7	3.1	3.7
Coliform Bacteria	4.6	6.9	4.6	6.9

Faecal coliforms	2.3	5.5	2.3	5.5

The wastewater generated in processing the fruit for ready to drink juice also has a notable organic load, primarily consisting of sugars and organic acids. The pH of the wastewater can vary and remains slightly acidic. While it may contain fewer solid particles compared to concentrate and puree processing, it still contains nutrients. Similar to concentrate and puree processing, the wastewater can contain colour and aroma compounds that affect its appearance and odour. **Error! Reference source not found.** shows Wastewater characterization for Juice production.

Table 4-8 Wastewater characterization for Juice production

Parameter	Mango (RTD)		Orange (RTD)	
BOD (mg/L)	63000	24000	63000	24000
COD (mg/L)	9000	39000	9000	39000
TS	1300	4300	1300	4300
TN	120	360	120	360
TP	30	58	30	58
E.Coli	2.7	3.6	2.7	3.6
Coliform Bacteria	4.5	6.4	4.5	6.4
Faecal coliforms	3.8	5.4	3.8	5.4

Wastewater generated from fruits and vegetables storage, which may include water used for cleaning and washing produce prior to storage, typically contains a combination of organic matter such as fruit and vegetable residues, as well as potential pesticides or chemical residues from agricultural practices. This wastewater may also carry suspended solids, including dirt and plant debris, as well as nutrients like nitrogen and phosphorus. Moreover, microorganisms like bacteria can be present due to contact with the produce. The specific characteristics of the wastewater can vary based on factors such as the produce types, storage conditions, and cleaning methods employed. **Error! Reference source not found.** shows Wastewater characterization for Fruits & Vegetables Storage.

Table 4-9 Wastewater characterization for Fruits & Vegetables Storage

Parameter	Fruits & Vegetables Storage	
BOD (mg/L)	400	1700
COD (mg/L)	4400	5900
TS	4600	18900
TN	68	92
TP	13	19
E.Coli	3.1	3.7
Coliform Bacteria	4.6	6.9

Faecal coliforms	2.3	5.5

The processing of oranges a citrus fruit of the rutaceae family and its chemical characterization is required to account for the negative impact on acquatic environments resulting from Essential oil residues. Several compounds found in these essential oils may have significant effects on aquatic ecosystems. Among the compounds listed **Error! Reference source not found.**, myrcene, when present in high concentrations, can have toxic effects on aquatic life. Limonene is relatively low in toxicity but can still pose a risk if found in large amounts. Linalool, geraniol, and geranyl acetate, when released in significant quantities, can be toxic to aquatic organisms and contribute to water pollution (Petretto et al., 2023).

Table 4-10 Chemical characterization from the processing of Oranges

Compound (mg/ml)	Limit
Myrcene	94.7 ± 1.
3-Carene	20.6 ± 1.2
Limonene	260.7 ± 2.4
beta-Ocimene	15.5 ± 0.4
gamma-Terpinene	10.9 ±1.2
Linalool	24.5 ± 0.3
6-Octenal,7-methyl-3-methylene	9.6 ±0.8
Citronellal	15.3 ± 0.1
Isonera	10.1 ± 0.2
Terpinen-4-ol	11.7 ± 0.5
Neral	88.3 ± 1.3
Geraniol	14.0 ± 0.9
Geranial	106.2 ± 1.6
Neryl acetate	31.8 ± 0.9
Geranyl acetate	23.5 ± 0.9

Wastewater generated during the tomato-to-ketchup processing possesses distinctive characteristics, primarily marked by its high organic content originating from tomato residues like peels and seeds, resulting in elevated biological and chemical oxygen demand. This wastewater often contains suspended solids, an acidic nature due to tomatoes' inherent acidity, and a red or orange hue from pigments like lycopene. Additionally, it may contain chemical additives and increased sodium levels used in processing, along with potential temperature variations depending on processing methods.

Table 4-11 Wastewater characterization for processing tomatoes to Ketchup

Parameter	Tomato to ketchup	
BOD (mg/L)	63000	24000
COD (mg/L)	9000	39000
TS	1300	4300
TN	120	360
TP	30	58

E.Coli	2.7	3.6
Coliform Bacteria	4.5	6.4
Faecal coliforms	3.8	5.4

4.2.2.5 Herbal Sector

The herbal sector produces wastewater that contains high levels of BOD and COD. According to Kumari and Tripathi, 2019, there is a high concentration of organic compounds in wastewater effluent released from the herbal sector due to the presence of high levels of BOD and COD. Error! Reference source not found. shows the wastewater characterization for the herbal sector.

Table 4-12:Herbal Sector Wastewater characterization

Parameter	Lower Limit	Upper Limit
BOD (mg/L)	5460	9000
COD (mg/L)	11980	15840
FOG (mg/L)	0	0
TSS	1000	1400
TDS	695	1170
TN	0	0
TP	0	0
Cl		
Zn	2.61	3.5
Fe	1.72	2.13

4.2.2.6 Fish sector

Wastewater produced during the processing of smoked fish is notably rich in organic matter stemming from fish scraps, skins, and oils, resulting in elevated biological oxygen demand (BOD) and chemical oxygen demand (COD). Additionally, the use of oils or fats in the smoking process contributes to the presence of challenging-to-remove oil and grease components. Salt is another significant factor, frequently employed for flavour and preservation, which elevates the salinity of the wastewater. The microbial load in this wastewater is considerable, including bacteria and potential pathogens, necessitating proper disinfection measures for public health safety. The temperature and pH levels can vary depending on the specific smoking methods and the type of fish being processed. Furthermore, fish processing wastewater contains nutrients like nitrogen and phosphorus that, if not effectively managed, could lead to nutrient loading in receiving water bodies.**Error! Reference source not found.** shows the wastewater characterisation for Smoked fish.

Table 4-13 Wastewater characterisation for Smoked fish

Parameter	Limit
BOD (mg/L)	3250
COD (mg/L)	13180
FOG (mg/L)	200

Wastewater generated during the processing of fish into omega-3 oil is notable for its high fat content, primarily comprising omega-3 oils and other lipids, resulting from the breakdown of fish. Some extraction methods may employ chemical solvents, introducing the need for their careful management. Organic matter released from the fish adds to the biological oxygen demand (BOD) of the wastewater. Additionally, nutrients such as nitrogen and phosphorus from the fish may be present, potentially contributing to nutrient loading if not properly controlled. **Error! Reference source not found.** shows the Wastewater characterisation for processing of Fish into omega 3 oil (Anh et al., 2021).

Table 4-14 Wastewater characterisation for processing of Fish into omega 3 oil

Parameter	Lower Limit	Upper Limit
BOD (mg/L)	500	1500
COD (mg/L)	1300	3250
FOG (mg/L)	156	2808
TSS	150	1100
TN	347	1200
TP	13	47

4.3 Wastewater estimation

Wastewater, quantifications were done only for sectors whose companies are already existing or are in the process of construction. The occupancy levels considered are 35%, 75% and 100% of the full occupancy for all the sectors. The lower, mean, and upper limit values of characterisation of wastewater from each industry at different percentages of occupancy are shown in the proceeding section. This characterisation has been based on the different sectors within the industries.

4.3.1 Fruit Processing sector

Error! Reference source not found. shows the Wastewater estimation for the fruit processing Sector. These values were obtained from the engagements with the Soroti fruit factory for processing of a total of 320 tons of fruit per day for both Teso foods and Soroti fruits factory limited.

Table 4-15 Wastewater estimation for the fruit processing Sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Orange (Concentrate)	Minimum Water Requirement	157	336	448
	Mean Water Requirement	430	920	1227
	Maximum Water Requirement	702	1505	2006
Mango (Concentrate)	Minimum Water Requirement	157	336	448
	Mean Water Requirement	430	920	1227
	Maximum Water Requirement	702	1505	2006
Oranges (RTD)	Minimum Water Requirement	6	13	17
	Mean Water Requirement	6	13	17
	Maximum Water Requirement	6	13	17
Mangoes (RTD)	Minimum Water Requirement	10	22	30
	Mean Water Requirement	10	22	30
	Maximum Water Requirement	10	22	30
Total	Minimum Water Requirement	330	707	943
	Mean Water Requirement	875	1876	2501
	Maximum Water Requirement	1421	3044	4059
Peak Flow	Minimum Water Requirement	495	1060	1414
	Mean Water Requirement	1313	2814	3751
	Maximum Water Requirement	2131	4567	6089

4.3.2 Fruits and vegetables storage sector

Error! Reference source not found. shows wastewater estimation for the Fruits and vegetable storage based on engagements with the Soroti fruit factory for processing of a total of 3 tons of fruit per day for both Teso foods and Soroti fruits factory limited for storage.

Table 4-16 Wastewater estimation for the Fuits and vegetable storage

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Fruit and vegetable storage	Minimum Wastewater Volume	1.4	3.1	4.1
	Mean Wastewater Volume	4.0	8.6	11.5
	Maximum Wastewater Volume	6.6	14.1	18.8
Peak Flow	**Minimum Wastewater Volume**	**2.15**	**4.62**	**6.16**
	Mean Wastewater Volume	**6.01**	**12.89**	**17.19**
	Maximum Wastewater Volume	**9.88**	**21.16**	**28.22**

4.3.3 Tomato to ketchup sector

Error! Reference source not found. shows wastewater estimation for the Tomato to ketchup sector with quantifications as provided from stakeholder engagements for processing approximately 40 tons of tomatoes per day for Teso foods ltd.

Table 4-17 Wastewater estimation for the Tomato to ketchup sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Tomato to ketchup	Minimum Wastewater Volume	49.8	106.8	142.4
	Mean Wastewater Volume	49.8	106.8	142.4
	Maximum Wastewater Volume	49.8	106.8	142.4
Peak Flow	**Minimum Wastewater Volume**	**75**	**160**	**214**
	Mean Wastewater Volume	**75**	**160**	**214**
	Maximum Wastewater Volume	**75**	**160**	**214**

4.3.4 Fish sector

Error! Reference source not found. shows wastewater estimation for the Fish sector for quantifications from stakeholder engagements for a ton of fish processed for smoking per day as well as 19.2 tons for omega 3 oil per day.

Table 4-18 Wastewater estimation for the Fish sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Smoked fish	Minimum Water Requirement	0	1	1
	Mean Water Requirement	1	1	2
	Maximum Water Requirement	1	2	2
Fish- omega oil	Minimum Water Requirement	101	216	288
	Mean Water Requirement	108	230	307
	Maximum Water Requirement	114	245	326
Total	Minimum Water Requirement	101	217	289

	Mean Water Requirement	108	232	309
	Maximum Water Requirement	115	246	329
Peak Flow	Minimum Water Requirement	152	325	434
	Mean Water Requirement	162	347	463
	Maximum Water Requirement	173	370	493

4.3.5 Herbal medicine sector

Error! Reference source not found. shows wastewater estimation for the Herbal medicine sector for daily quantities of 5 tons of product as provided from stakeholder engagements.

Table 4-19 Wastewater estimation for the Herbal medicine sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Herbal medicine	Minimum Wastewater Volume	4.4	9.4	12.5
	Mean Wastewater Volume	45.9	98.4	131.3
	Maximum Wastewater Volume	87.5	187.5	250.0
Peak flow	**Minimum Wastewater Volume**	**6.56**	**14.06**	**18.75**
	Mean Wastewater Volume	**68.91**	**147.66**	**196.88**
	Maximum Wastewater Volume	**131.25**	**281.25**	**375.00**

4.3.6 Agro foods sector

Error! Reference source not found. shows wastewater estimation for the Agro foods sector for quantities obtained from different stakeholder engagements

Table 4-20 Wastewater estimation for the Agro foods sector

Sub sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Sweet potato puree	Minimum Water Requirement	0.1	0.2	0.3
	Mean Water Requirement	0.1	0.2	0.3
	Maximum Water Requirement	0.1	0.3	0.3
Food/grain	Minimum Water Requirement	135.1	289.5	386.0
	Mean Water Requirement	1418.6	3039.8	4053.0
	Maximum Water Requirement	2702.0	5790.0	7720.0
Peanut oil	Minimum Water Requirement	3.1	6.7	8.9
	Mean Water Requirement	7.8	16.7	22.3
	Maximum Water Requirement	12.5	26.8	35.7
Cassava - Ethanol	Minimum Water Requirement	109.2	234.0	312.0
	Mean Water Requirement	395.9	848.3	1131.0
	Maximum Water Requirement	682.5	1462.5	1950.0
Cassava - Starch	Minimum Water Requirement	212.8	456.0	608.0
	Mean Water Requirement	269.3	577.1	769.5
	Maximum Water Requirement	332.5	712.5	950.0
Total	Minimum Water Requirement	460	986	1315
	Mean Water Requirement	2092	4482	5976
	Maximum Water Requirement	3730	7992	10656
Peak Flow	Minimum Water Requirement	690	1480	1973

	Mean Water Requirement	3137	6723	8964
	Maximum Water Requirement	5594	11988	15984

4.3.7 Dairy Sector

Error! Reference source not found. shows wastewater estimation for the Dairy sector for the proposed 10,000 liters of milk.

Table 4-21 Wastewater estimation for the Dairy sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Dairy - milk bulking and cooling	Minimum Water Requirement	4.2	9.0	12.0
	Mean Water Requirement	6.1	13.1	17.5
	Maximum Water Requirement	7.0	15.0	20.0
Dairy - yoghurt	Minimum Water Requirement	3.7	12.9	18.4
	Mean Water Requirement	3.7	12.9	18.4
	Maximum Water Requirement	3.7	12.9	18.4
Dairy- Ice cream	Minimum Water Requirement	0.8	2.8	3.9
	Mean Water Requirement	1.2	4.1	5.9
	Maximum Water Requirement	1.6	5.5	7.9
Total	Minimum Water Requirement	9	25	34
	Mean Water Requirement	11	30	42
	Maximum Water Requirement	12	33	46
Peak Flow	Minimum Water Requirement	13	37	51
	Mean Water Requirement	16	45	63
	Maximum Water Requirement	18	50	69

4.3.8 Domestic demand sector

Error! Reference source not found. shows the wastewater estimation for the Domestic demand sector for all the 3250 employees estimated to be within the park.

Table 4-22 Wastewater estimation for the Domestic demand sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone		
		35%	75%	100%
Domestic demand	Minimum Wastewater Volume	39.8	85.3	113.8
	Mean Wastewater Volume	64.0	137.1	182.8
	Maximum Wastewater Volume	91.0	195.0	260.0
Peak flow	**Minimum Wastewater Volume**	**59.72**	**127.97**	**170.63**
	Mean Wastewater Volume	**95.98**	**205.66**	**274.22**
	Maximum Wastewater Volume	**136.50**	**292.50**	**390.00**

4.3.9 Concrete production sector

Error! Reference source not found. shows Wastewater estimation for the Concrete sector for quantities provided by Sanqua Engineering limited.

Table 4-23 Wastewater estimation for the Concrete sector

Sector	Wastewater Volume (m^3)	Percentage Development of Freezone

		35%	75%	100%
Concrete	Minimum Water Requirement	0.3	0.7	0.9
	Mean Water Requirement	0.5	1.1	1.4
	Maximum Water Requirement	0.7	1.5	2.0
Peak Flow	**Minimum Wastewater Volume**	**0.48**	**1.02**	**1.36**
	Mean Wastewater Volume	**0.74**	**1.59**	**2.12**
	Maximum Wastewater Volume	**1.06**	**2.27**	**3.03**

The summary of the wastewater estimation for the Industrial Park is shown in Error! Reference source not found..

Sector	**Wastewater Volume (m^3)**	**Percentage Development of Freezone**		
		35%	**75%**	**100%**
Sweet potato puree	Minimum Water Requirement	0.10	0.20	0.27
	Mean Water Requirement	0.11	0.23	0.31
	Maximum Water Requirement	0.12	0.25	0.34
Dairy bulking and cooling	Minimum Water Requirement	4.2	9.0	12.0
	Mean Water Requirement	6.1	13.1	17.5
	Maximum Water Requirement	7.0	15.0	20.0
Food/grain	Minimum Water Requirement	135.1	289.5	386.0
	Mean Water Requirement	1418.6	3039.8	4053.0
	Maximum Water Requirement	2702.0	5790.0	7720.0
Herbal Medicine	Minimum Water Requirement	4.4	9.4	12.5
	Mean Water Requirement	45.9	98.4	131.3
	Maximum Water Requirement	87.5	187.5	250.0
Smoked fish	Minimum Water Requirement	0.4	0.8	1.1
	Mean Water Requirement	0.6	1.2	1.7
	Maximum Water Requirement	0.8	1.7	2.2
Fish- omega oil	Minimum Water Requirement	100.8	216.0	288.0
	Mean Water Requirement	107.5	230.4	307.2
	Maximum Water Requirement	114.2	244.8	326.4
Concrete	Minimum Water Requirement	0.3	0.7	0.9
	Mean Water Requirement	0.5	1.1	1.4
	Maximum Water Requirement	0.7	1.5	2.0
Peanut oil	Minimum Water Requirement	3.1	6.7	8.9
	Mean Water Requirement	7.8	16.7	22.3
	Maximum Water Requirement	12.5	26.8	35.7
Cassava - Ethanol	Minimum Water Requirement	109.2	234.0	312.0
	Mean Water Requirement	395.9	848.3	1131.0
	Maximum Water Requirement	682.5	1462.5	1950.0
Cassava - Starch	Minimum Water Requirement	212.8	456.0	608.0
	Mean Water Requirement	269.3	577.1	769.5

	Maximum Water Requirement	332.5	712.5	950.0
Dairy - yoghurt	Minimum Water Requirement	3.7	12.9	18.4
	Mean Water Requirement	3.7	12.9	18.4
	Maximum Water Requirement	3.7	12.9	18.4
Tomato Ketchup	Minimum Water Requirement	49.8	106.8	142.4
	Mean Water Requirement	49.8	106.8	142.4
	Maximum Water Requirement	49.8	106.8	142.4
Fruit storage	Minimum Water Requirement	1.4	3.1	4.1
	Mean Water Requirement	4.0	8.6	11.5
	Maximum Water Requirement	6.6	14.1	18.8
Orange (Concentrate)	Minimum Water Requirement	156.8	336.0	448.0
	Mean Water Requirement	429.5	920.4	1227.2
	Maximum Water Requirement	702.2	1504.8	2006.4
Mango (Concentrate)	Minimum Water Requirement	156.8	336.0	448.0
	Mean Water Requirement	429.5	920.4	1227.2
	Maximum Water Requirement	702.2	1504.8	2006.4
Oranges (RTD)	Minimum Water Requirement	5.8	12.5	16.7
	Mean Water Requirement	5.8	12.5	16.7
	Maximum Water Requirement	5.8	12.5	16.7
Mangoes (RTD)	Minimum Water Requirement	10.4	22.4	29.8
	Mean Water Requirement	10.4	22.4	29.8
	Maximum Water Requirement	10.4	22.4	29.8
Dairy- Ice cream	Minimum Water Requirement	0.8	2.8	3.9
	Mean Water Requirement	1.2	4.1	5.9
	Maximum Water Requirement	1.6	5.5	7.9
Employees	Minimum Water Requirement	39.8	85.3	113.8
	Mean Water Requirement	64.0	137.1	182.8
	Maximum Water Requirement	91.0	195.0	260.0
Total (Industrial)	**Minimum Water Requirement**	**855.2**	**1,838.7**	**2,453.1**
	Mean Water Requirement	**3,078.8**	**6,604.1**	**8,807.0**
	Maximum Water Requirement	**5,308.0**	**11,381.5**	**15,177.1**
Total (Industrial+Domestic)	**Minimum Wastewater Volume**	**895.0**	**1,924.0**	**2,566.8**
	Mean Wastewater Volume	**3,142.8**	**6,741.2**	**8,989.8**
	Maximum Wastewater Volume	**5,399.0**	**11,576.5**	**15,437.1**
Peak Flow	**Minimum Wastewater Volume**	**1,342.56**	**2,886.00**	**3,850.24**
	Mean Wastewater Volume	**4,714.20**	**10,111.74**	**13,484.75**
	Maximum Wastewater Volume	**8,098.56**	**17,364.74**	**23,155.61**

4.4 Wastewater Management Options

The maximum volume of wastewater to be treated is 23,156 m^3/day. The proposed location of the wastewater management facilities is along the southern boundary of the industrial park. The available acreage, based on the CAD drawings provided by UIA, is approximately 5 acres.
The wastewater management options include the following:

i. Utilization of the existing wastewater management facilities
ii. Construction of wastewater management facilities for each of the industries
iii. Construction of waste stabilization ponds
iv. Construction of a wastewater treatment plant

4.4.1 Utilization of the Existing Wastewater Management Facilities

The existing WSP in Soroti city are located approximately 8km from the industrial park. The infrastructure required to deliver wastewater to the facility comprises a collection sump, lifting station, sewer pumping mains, a collection chamber and sewer gravity mains.
However, the reserve treatment capacity is limited due to high demand for treatment of faecal sludge. Hence this option is not considered viable for the industrial park.

4.4.2 Construction of Wastewater Management Facilities at each of the factories

This wastewater management option would address challenges associated with treatment of some pollutants and variation in the quantity of wastewater produced by the industries.

The wastewater pollution load from different sectors indicates that the industries share types of pollutants, with the exception of dairy sector, fish sector and herbal medicine sector. The processing of milk results in the extraction of quantities of fats and oils that would require enzymatic digestion. The processing of fish for smoked fish and omega 3 oil results in wastewater rich in organic matter, suspended matter as well as oil and grease. The treatment of this wastewater would generally require sedimentation and filtration as the physical treatment, Addition of chemicals as coagulants to remove the oil and grease as the chemical treatment and breakdown of organic matter as the biological treatment. Hence the treatment of the wastewater containing the aforementioned pollutants within the industries would optimise the use of reagents and provide efficient monitoring of the wastewater influent and effluent.

Fruit processing companies such as Soroti Fruits Factory Limited, Komolo Foods and Beverages, and Teso Foods are advised to collaborate on pre-treatment facilities due to the similarities in their waste materials. Additionally, considering the existing treatment plant at Soroti Fruits Factory Limited, the consultant recommends upgrading it to accommodate the expected increase in the processing load.
Seed oil processing businesses, specifically Green Gold International Limited and Asalalamaal Limited, are also encouraged to share wastewater treatment facilities owing to the similarity in their wastewater composition.
In the case of grain processing industries, which include Mega Holdings Limited, Komolo Foods and Beverages, Serere Agro Enterprise Limited, and Pela Commodities, it is recommended that they explore the option of sharing wastewater treatment facilities.
However, industries involved in herbal, fish, concrete, and dairy processing are recommended to pretreat their wastewater in order to remove inorganic compounds by ion exchange. The pretreatment by the individual companies is necessary because the characteristics of the wastewater are distinct and require specialized treatment.
All the industries invited on site will be compelled to use the wastewater treatment plant that will be designed for further treatment of their waste and it should also be noted that this treatment plant will be managed by National water and Sewerage Cooperation as a public entity.

In addition, there is a variation in the quantity of wastewater produced at the industries.. High capital investment costs would be incurred for the construction of sewer lines to convey the volume of wastewater

4.4.3 Construction of waste stabilization ponds

Waste stabilization ponds decrease the organic content and eliminate pathogens from the wastewater. Waste stabilization ponds utilize natural treatment mechanisms that require time due to relatively slow removal rates. As a result, they necessitate larger surface areas.

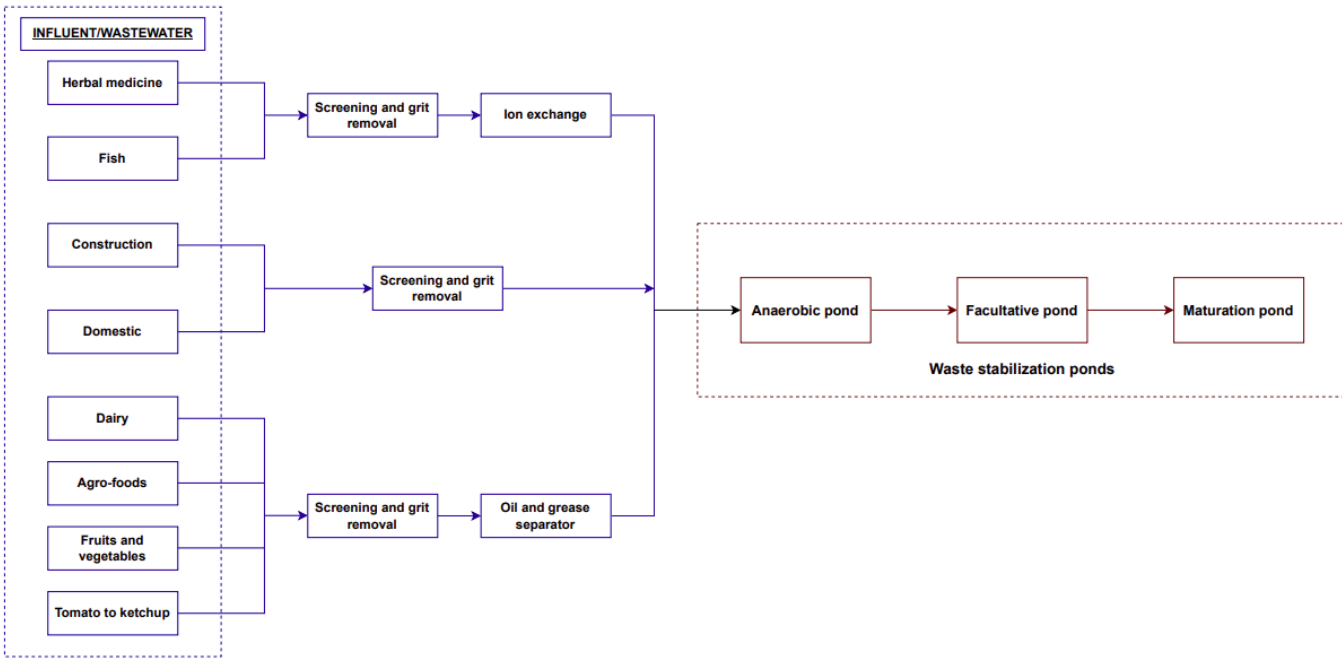

Figure 4-3 Proposed wastewater management strategy using waste stabilization ponds

Waste Stabilization Ponds have low operation and maintenance costs but require large area. The available acreage for the construction of wastewater management facility is 5 acres. The minimum required acreage for the construction of WSP is 16 acres, based on the minimum volume of wastewater.
However, the WSP are not effective in the treatment of inorganic pollutants such as Zinc, Chlorides, Sodium, Potassium, Cyanide, etc. The treatment of the wastewater would require additional units for ion exchange and pH control. Hence this option is not suitable for the industrial park.

4.4.4 Construction of a wastewater treatment plant

The wastewater treatment plant comprises of the following treatment processes:

i. Pre-treatment. This comprises of mechanical and biological pretreatment processes such as screening, oil and grease separation, enzymatic digestion and primary sedimentation
ii. Primary treatment: This comprises of processes such as biological and/or chemical treatment processes such as secondary sedimentation, anaerobic digestion, chemical oxidation and ion exchange
iii. Secondary treatment: This comprises of biological and/or chemical treatment processes such as filtration, aerobic digestion and pH control
iv. Tertiary treatment: This comprises of polishing treatment such as final treatment in a swamp or constructed wetland. Activated carbon filtration is also considered under tertiary treatment.

The treatment processes result in accumulation of sludge. The sludge is dried and disposed of in a landfill. The sludge containing hazardous materials such as heavy metals must be appropriately handled, transported by private means and disposed of in the Aminit landfill. The existing public transportation options for waste disposal to the landfill are inadequate, as they can only make a maximum of six trips per week. Therefore, the consultant suggests employing private transportation methods, funded through a collective effort by all industries, to handle the transportation of this sludge.

4.4.5 Selected wastewater management processes

The selected wastewater management processes entail initial pre-treatment at all the respective industries before all the wastewater is transferred to the wastewater treatment plant as detailed in **Error! Reference source not found.**

The proposed wastewater management strategy is detailed below:

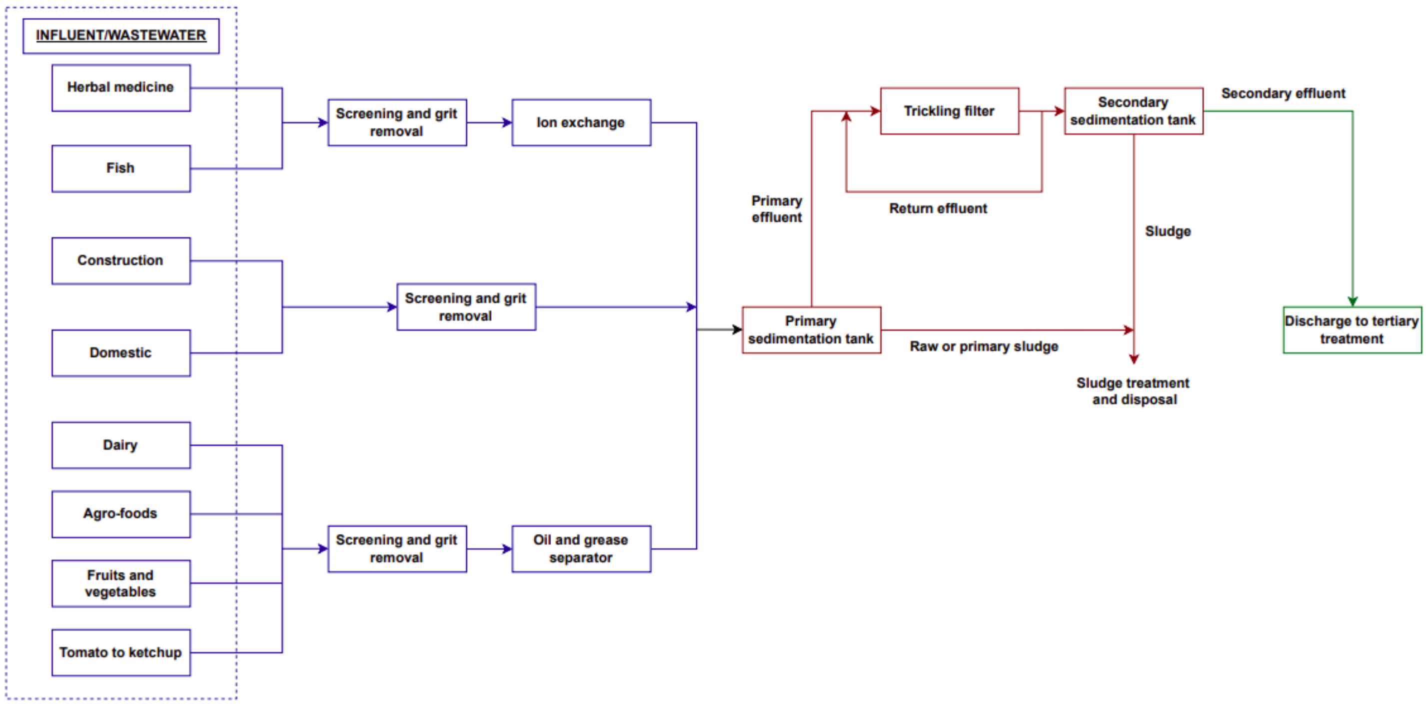

Figure 4-4 Proposed wastewater management strategy using wastewater treatment plants.

i. Industries where Herbal medicine and fish processing are carried out should have pretreatment processes comprising of screening, grit removal and ion exchange. The maximum wastewater flow from these sectors at 100% production will be 250m^3 and 330m^3 per day of maximum wastewater flow respectively.
ii. Industries where construction and domestic demand are carried out should have pretreatment processes comprising of screening and grit removal. The maximum wastewater flow from these sectors at 100% production will be majorly due to domestic demand of 260m^3 per day of maximum wastewater flow respectively.
iii. Industries where dairy, Agro-foods, fruits and vegetables and processing of tomatoes to ketchup are carried out should have pretreatment processes comprising of screening, grit removal as well as oil and grease separation. The maximum wastewater flow from these sectors at 100% production will be majorly due to domestic demand of 46m^3, 10,656m^3, 40.59m^3 and 142.4m^3 per day of maximum wastewater flow respectively.
iv.

i. The wastewater from all the industries will be conveyed through gravity sewer lines to the wastewater treatment plant where it will undergo treatment to achieve appropriate levels of effluent quality before being discharged into the environment.

The wastewater treatment structures at the treatment plant are listed below:

- Screen and Grit Chamber.. The wastewater will pass through a screening process and a grit trap to eliminate any remaining large solid waste particles that might have survived the preliminary treatment carried out at the industrial facilities
- Primary Sedimentation Tank. The wastewater will undergo ion exchange in this chamber under chemical oxidation. This will aid in elimination of inorganic pollutants such as Iron and other Total Dissolved Solids. Under routine operation and maintenance, the chamber will be de-sludged, and the sludge dried before disposal in the landfill.
- Trickling Filters: The wastewater will undergo biological treatment where the organic matter in the wastewater will be broken down.
- Secondary Sedimentation Tank. The wastewater will undergo further clarification where suspended solids will settle to form sludge. The pH of the wastewater must be monitored in this chamber and pH correction carried out as required.
- Constructed Wetlands. The constructed wetlands will contain granulated activated carbon. The wastewater will be discharged into the wetlands for polishing treatment. The activated carbon will enable further treatment of residual inorganic pollutants such as Potassium, Chlorides, Zinc and Iron.

There will be minimal power requirements at the wastewater treatment plant for the operation of pumps and associated electrical and mechanical equipment. The treatment plant will be connected to the national grid and standby power provided by a diesel generator.

The industrial park is not yet fully developed and the rate of development is not known at this stage. The estimated capacity of the wastewater treatment plant at 100% development ranges between a minimum flow of 8098.56m^3/day and a maximum flow of 23155.61m^3/day. The Consultant proposes that the construction of the wastewater treatment plant is phased to provide for two parallel treatment lines to allow for the growth in the rate of wastewater production. The available acreage is not sufficient to construct the wastewater treatment plant and requisite additional infrastructure.

A wastewater treatment plant of capacity 4000m^3/day can be constructed under the first phase, within the available acreage. However, this will require further assessment during feasibility studies and detailed design. After discussions with stakeholders, we were informed by the environmental authority that the city's urban planning authority intends to build its own wastewater treatment facility. The preliminary discussion indicate that the proposed location of the wastewater management facility is near the industrial park. This presents an opportunity for shared facilities with the city. However, we were not informed of the timelines about when the construction of the treatment facility would be completed.

4.4.6 Operation and maintenance

NWSC is mandated to provide water supply and sewerage services in urban centers. NWSC has the technical capacity and experience to operate the wastewater treatment plant. The Consultant proposes that the operation and maintenance of the plant is undertaken by NWSC.

Based on the proposal to have pre-treatment facilities in some identified industries, the Consultant recommends that the operation of these facilities is carried out by NWSC. This will enable technical support for the chemical and biological pre-treatment processes and monitoring and control of the wastewater quality received at the treatment plant.

The role of the industries in the operation and maintenance of the wastewater management facilities are:

- Payment of utilities bills that will include a surcharge cost towards payment for sewerage services
- Separation of solid waste from wastewater during operations. This will prevent clogging of the manholes and screens.
- Timely communication to NWSC on changes to cleaning agents, chemical additives, etc that affect the quality and quantity of the wastewater

The pump station will be connected to the national grid. A standby power source is required and this can take the form of solar power. Solar power can be harnessed by mounting solar panels on top of the warehouse roofing sheets. The power requirements at the treatment plant will be assessed at the feasibility study stage and the solar power system will be sized.

Utilizing wastewater treatment plants employs a minimal green approach specifically at the stage of constructed wetlands which will play a pivotal role in promoting biodiversity by offering habitats for diverse plant and animal species. Additionally, they will act as carbon sinks, aiding in carbon sequestration. The methane that is usually obtained from this stage is very minimal owing to the fact that the use of constructed wetlands are the last stage of this wastewater treatment facility and hence this methane cannot be captured for any useful purpose.

Treatment of wastewater to effluent discharge standards will ensure protection of the nearby wetland and downstream users where the effluent will be discharged. The wastewater treatment using this facility will result in a Biological Oxygen Demand (BOD) removal of at least 70% and a Chemical Oxygen Demand (COD) removal of at least 75% as per (United nations, 2016). Despite the promising outcomes, precise percentage reductions in water pollution will require a comprehensive study, considering factors such as wastewater quality and operating conditions.

4.4.7 Summary of Recommendations from the RECP report

4.4.7.1 Recommendations on Wastewater Management for Industries

The RECP report provides the following recommendations with regards to wastewater management;

i) The RECP field report offers a comprehensive set of recommendations for improving wastewater management within industrial processes. These recommendations aim to enhance both the quality of wastewater and reduce its overall volume. They underscore the importance of proactive measures, such as regular inspections and prompt repairs to address leakages and spillages in storage units and pipes. Spill collection trays are suggested for capturing spilled products for reprocessing, which can contribute to waste reduction.

ii) Efforts to prevent the entry of solid particles into wastewater are encouraged through the installation of grids over drains. Proper disinfection is emphasized, with a focus on using specific chemicals tailored to contaminants in different areas of industrial processes. This approach ensures more effective and environmentally responsible treatment of wastewater. Additionally, using cleaning agents in the correct concentrations and following manufacturer instructions is crucial to minimize the overall wastewater generated.
iii) Optimising processes, such as reducing the use of phosphoric acid in degumming, potentially through improvements in neutralization or the adoption of alternative methods like enzymatic degumming are encouraged. Proactive maintenance protocols for mechanical equipment are encouraged to mitigate the risk of leaks and other issues contributing to wastewater generation. Staff education and training are deemed essential, not only to raise awareness about wastewater reduction and quality improvement but also to ensure ongoing compliance with these best practices.

The consultant suggests that, if the treated wastewater complies with the necessary quality standards, it can be released in a controlled manner to minimize its impact on the downstream channel and surrounding area. Nevertheless, it's essential to acknowledge that the environmental effects of effluent discharge can vary, influenced by factors like the quality of the treated wastewater, the discharge volume, and the characteristics of the receiving water body (Kienle et al., 2019).

Generally, substantial quantities of discharged treated wastewater can lead to alterations in water temperature, salinity, and nutrient levels within the receiving water body. These changes can have consequences on aquatic life and their habitats.

4.4.7.2 Resource recovery

4.4.7.2.1 Waste stabilisation ponds

Methane retrieval from anaerobic ponds used in wastewater treatment is proposed. The methane is generated from the pond through anaerobic digestion. Anaerobic digestion, a biological method, entails the decomposition of organic matter in an oxygen-depleted environment. This microbial action yields biogas, primarily composed of methane, the key component of natural gas.
One effective technique for this purpose involves utilizing covered anaerobic lagoons equipped with airtight covers, ensuring the secure containment and efficient collection of methane (Michael et al., 2020). Regular maintenance and quality control measures are essential to uphold the reliable and sustainable recovery of methane from these anaerobic ponds, offering a valuable energy source and promoting environmentally conscious wastewater treatment practices.

4.4.7.2.2 Wastewater management facilities

Phosphorus removal and recovery are most commonly carried out during the tertiary treatment phase. Tertiary treatment processes are specifically designed to further reduce the concentration of nutrients, including phosphorus, in the treated wastewater.
One common approach to phosphorus recovery involves chemical precipitation. In this method, chemicals like aluminium sulphate and ferric chloride are introduced into the wastewater, leading to the formation of a solid precipitate that can be extracted from the water (Hisao, 2018). Subsequently, this precipitate undergoes processing to reclaim the phosphorus. An alternative method for phosphorus recovery from wastewater is anaerobic digestion. Here, bacteria decompose organic matter in the wastewater in the absence of oxygen, yielding biogas primarily composed of methane. After removing non-methane

components from the biogas for energy utilization, the residual sludge can be treated to extract phosphorus. Another viable technique for phosphorus recovery is struvite precipitation (Hisao, 2018). This method entails the addition of magnesium and ammonia to the wastewater, resulting in the formation of struvite, a solid precipitate that can be separated from the water. Subsequently, this precipitate is processed to reclaim the phosphorus.

Managing wastewater containing oil refining residues, a prevalent approach for treatment involves coagulation and flocculation. In this method, flocculation is done. The formed flocs are subsequently processed to reclaim the oil and other valuable constituents. Another technique for addressing oily wastewater is membrane filtration. Here, a membrane is employed to effectively segregate the oil and other contaminants from the water, allowing for the recovery and reuse of the separated oil. Biological treatment presents another viable option for treating oily wastewater. In this process, bacteria play a pivotal role in decomposing the organic components within the wastewater. These bacteria produce biogas, which can serve as an energy source (Kaya & Hung, 2021).

4.4.8 Review of Resource Recovery Options

4.4.8.1 Methane Recovery

The proposed recovery of methane from the waste stabilization ponds can be carried out by constructing a dome at the anaerobic pond. The methane would then be stored in gas holders at the wastewater treatment site. The methane can be used for heating.

4.4.8.2 Phosphorus Recovery

The recommendations identified two options for the recovery of phosphorus. The former option, where the phosphorus is recovered after tertiary treatment is proposed. The recovery will be done by creating a bypass from the effluent main into a reinforced concrete tank. In this tank, the chemical precipitation will be carried out. An additional treatment unit for final clarification will be included before disposal of the effluent. The precipitate is dried and can be packaged to use as fertilizer.

5. Solid Waste Management

5.1 Solid waste characterization

Solid waste generated within the Soroti industrial park is characterized by its diverse composition, including organic materials, plastics, textiles, metals, paper, and cardboard. This waste emanates from various sectors, such as dairy, concrete manufacturing, fruit processing, herbal medicine, potato processing, agro-grains processing, fish processing, cassava processing, tomato processing and seed oil processing. The Table 5-1 below shows the potential solid waste characteristics and handling generated by the various sectors in the park.

Table 5-1: Table showing the various sectors and type of solid waste generated

Sector	Solid waste	Storage/ Disposal
Dairy		
Milk Bulking and Cooling	Particles, sediments, sludge	Biodigester
Yoghurt	Particles, sediments, sludge	Biodigester
Ice cream	Particles, sediments, sludge	Biodigester
Fruits		
Fruits Storage	Organic chippings	Biodigester/composting
	spoilt fruits	
	Waste from packaging materials	Recycling
Fruits Processing	Peelings, pith, fruit mash	Butter/Essential oils
	Waste from Packaging material	Recycling
Herbal Medicine		
Herbal	Packaging waste, Non-hazardous and hazardous waste, Lab waste	Incineration/recycling
	Expired raw materials	Incineration
Seed Oils		
Peanuts oil	Shells, skins, meal	Animal feeds/Composting
Sorghum Processing		

Sorghum Floor	Husks, Bran, Germ	Valorization for Carbon dioxide
Fish processing		
Smoked Fish	Viscera, heads, scales	Animal feeds/Biodigester
Tomato Processing		
Ketchup	Seeds, pulp and skins	Animal feeds
Concrete		
Concrete	Unused concrete	Reusing
Potato Processing		
Puree	Potato Peelings	Animal feeds/Biodigester
Cassava		
Starch	Peelings, fibrous residues	Biochar/Animal feeds
Ethanol	Dry cake	Biochar/Animal feeds

5.1.1 Volume of solid waste generated

The daily solid waste generation in kilograms (kg) without valorization at the industrial park is summarized in the Table 5-2 below.

Table 5-2: Daily Solid waste generation (kg) and characterization at the Soroti Industrial Park

Characterization of Solid waste	Level of Development		
	35%	75%	100%
Organic waste	143,146.1	411,513.1	574,417.5
Plastics	251.8	539.5	719.4
Paper and cardboards	253.8	543.8	725.0
Dust and other impurities	83.5	178.9	238.5
Others	1,416.8	3,035.9	4,047.9
Total	145,151.9	415,811.2	580,148.2

5.1.2 Solid waste generated by each sector

The estimated daily solid waste generation without valorization for each sector in kg is shown in the **Error! Reference source not found.** below

Table 5-3: Characteristics and daily quantities (kg) of solid waste produced by the different sectors in the Soroti Industrial Park

Sector	Characterization of solid waste	Level of Development		
		35%	75%	100%
Fruits				
Fruits Storage	Organic waste	12.6	27	36
	Dust and other impurities	31.5	67.5	90
	Plastics	18.9	40.5	54
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Fruits Processing	Organic waste	128800	276000	368000
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Herbal Medicine				
Herbal Medicine	Organic waste	0	0	0
	Dust and other impurities	83.125	178.125	237.5
	Plastics	166.25	356.25	475
	Metal	0	0	0
	Paper and cardboards	83.125	178.125	237.5
	Textile	0	0	0
	Others	0	0	0
Seed Oils				
Peanuts Oil	Organic waste	50008	107160	142880
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Grain Processing				
Sorghum Flour	Organic waste	77200	270200	386000
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0

Sector	Characterization of solid waste	Level of Development		
		35%	75%	100%
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Fish Processing				
Smoked Fish	Organic waste	75.99375	162.8438	217.125
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	2.75625	5.90625	7.875
Tomato Processing				
Ketchup	Organic waste	1044.75	2238.75	2985
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Concrete Processing				
Concrete	Organic waste	0	0	0
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	1414	3030	4040
Cassava Processing				
Starch	Organic waste	7000	15000	20000
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Ethanol	Organic waste	6825	14625	19500
	Dust and other impurities	0	0	0

Sector	Characterization of solid waste	Level of Development		
		35%	75%	100%
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0
Potato Processing				
Puree	Organic waste	8.701	18.645	24.86
	Dust and other impurities	0	0	0
	Plastics	0	0	0
	Metal	0	0	0
	Paper and cardboards	0	0	0
	Textile	0	0	0
	Others	0	0	0

5.1.3 Domestic solid waste generated in the Soroti IBP

The domestic solid waste in the industrial park is majorly generated by the workers, visitors and other people from the different sectors of the park. The estimated number of people in the park is about 3250 people. The Table 5-4 below shows the daily estimated quantities of solid waste generation per 3250 people.

Table 5-4: Daily domestic solid waste generation

Characterization of solid waste	Solid Waste (kg)
Organic waste	1,706.3
Plastics	243.8
Paper and cardboards	487.5

5.2 Components of solid waste management

5.2.1 Generation

The commencement of the waste management process begins with solid waste generation. This phase involves the production of solid waste materials via diverse activities within the industrial park. These activities encompass the disposal of the peelings of fruits and vegetables, the discarding of leaves, stems, husks, meal as well as the use of packaging materials like plastics. The volume and composition of the waste generated are intricately tied to the production methods and patterns in use.

5.2.2 Storage

The storage of solid waste at the industrial park will involve the use of storage facilities such as waste bins, containers, communal depots, or designated areas for larger waste items preventing littering. Cold storage will be provided for the storage of solid waste from the fish sector. Table 5-5 shows the cold storage requirements for the fish sector.

Table 5-5: Cold storage for waste from the fish sector

Parameter	Daily	Weekly	Monthly
Waste from fish sector (kg)	78.8	551.3	2362.5
Density of the waste (kg/m3)	1000.0	1000.0	1000.0
Volume of waste (m3)	0.1	0.6	2.4

5.2.3 Collection

Various collection methods will be employed at the industrial park and these include the following;

- **On-Site Collection:** This will involve collection of waste directly into on-site bins or containers provided around the industrial park. Compactors may also be used to reduce waste volume.
- **Centralized Collection:** Only a single truck currently exists in Soroti city to transport waste to Aminit landfill site therefore private waste collection services will be employed to pick up waste from centralized points within the industrial park at least twice a week. Private waste collection services are assumed to be more cost effective as opposed to a service managed by the park due to costs of hiring trucks, workers and other associated transportation costs.

5.2.4 Transportation

Once waste materials have been gathered, they must be conveyed to their ultimate destinations, which may encompass recycling facilities, incineration plants, landfill sites, or dedicated treatment centers. The solid waste that will not be valorized will be conveyed to the Aminit landfill by private trucks, occupying a 9-acre tract of land situated approximately 5 km away from the industrial park. Figure 5-1 below shows the location of Soroti Industrial Park and Aminit landfill site

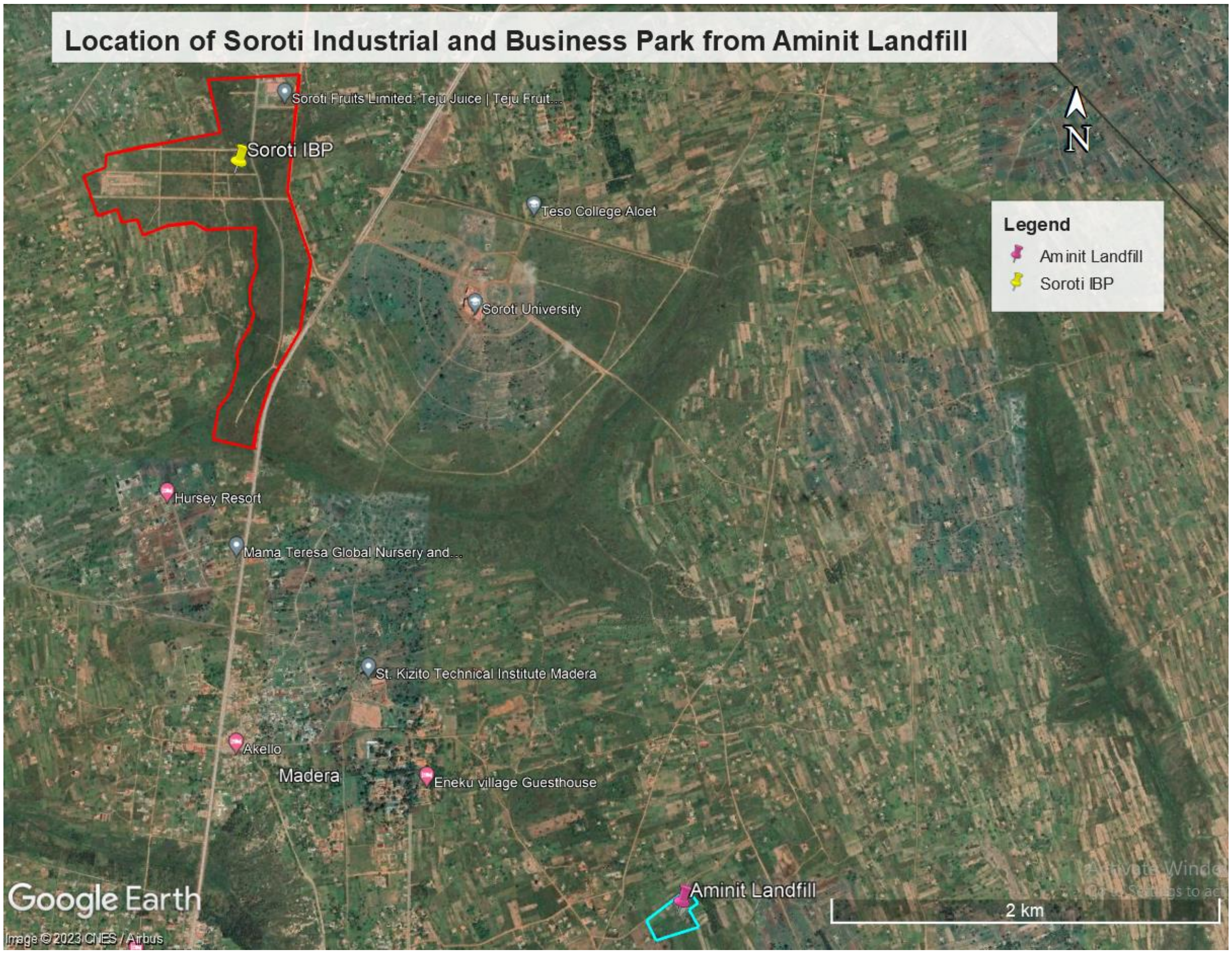

Figure 5-1: Location of Soroti Industrial and business Park from Aminit landfill

5.2.5 Treatment and Disposal

The concluding phase of solid waste management entails the careful and secure handling of waste to reduce potential environmental and health hazards.

5.3 Waste Valorization

Waste valorization is the process of converting waste materials into more useful products including chemicals, materials and fuels (Arancon et al., 2013). Various valorization techniques have been recommended to be taken up for the Soroti Industrial Park and these include;

- Extraction of Essential Oils from the waste: Recovered peel represents about 0.3% of the fruit intake, this oil will be recovered from orange peel using a separate oil extraction system placed upstream of the juice extractors.
- Extraction of butter from mango kernel: Mango kernel butter can be extracted in many ways but cold press extraction is the best and proposed option to be adopted.
- Production of Animal feeds from fruit and seed oil processing: Rejected fruits from grading, peel, washed pulp and rag from extraction are sent to the feed mill where they are dried and turned into pellets for animal feeds. Tomato seeds are rich in K, Mg, Na and Ca which are required for animal

growth therefore these are also processed into animal feeds. It is also proposed that lycopene be extracted from the tomato skin however, this is pending a market assessment.

- Carbon dioxide recovery from Ethanol processing facility: The collected carbon dioxide during fermentation will be collected, compressed, dried, purified and liquefied.
- Recycling: Waste at the Aminit landfill site will be sorted and the recyclable materials such as paper, cardboard, plastics, glass are removed. These items will be collected and sold to recycling companies in order to produce new products.
- Manufacture of biochar: cassava peels from the processing of cassava to starch will be valorized by pyrolysis to produce biochar which is a great product to improve on the soil fertility and to limit the use of chemical fertilizers.

5.4 Solid Waste Management Techniques

All the solid waste from the Soroti city is currently managed at the Aminit landfill site. The solid waste in the city majorly comes from the Soroti market and only a single truck which makes 6-7 trips weekly is available to transport this waste to the landfill site. The solid waste from the industrial park is also currently taken to the Aminit landfill except for Soroti Fruit Factory which dumps its solid waste at another landfill site known as Telangot.

When the solid waste reaches the Aminit landfill, it undergoes sorting to remove materials like paper, polythene and plastic bottles for recycling and metal to be sold as scrap. Four (4) casual labourers are present at the landfill to do the sorting and one data entry clerk. However, these labourers are not provided with personal protective equipment and as a result they often fall sick due to over exposure to this solid waste. The solid waste is left to undergo decomposition and manure is later sieved out into Grade A (fine and clean manure) and Grade B manure. Leachate from the solid waste is however not managed therefore posing potential groundwater and surface water pollution.

A Public Private Partnership (PPP) is proposed by the consultant to develop and upgrade the Aminit landfill site. Some of the improvements to be done include the establishment of a leachate and gas collection system to curb pollution, site office for the management of the landfill, access roads, weigh bridge for invoicing and management purposes, a sorting bay and proper fencing of the site. The Aminit landfill will be shared together with the general public where charges for disposing waste into this landfill will be collected by Soroti city administration. This creates a win for both the private and public sector in the sense that solid waste from both parties will be safely managed at the landfill site and the revenue collected will be used for running the various activities at the landfill. Figure 5-2 shows the current state of Aminit landfill whereas Figure 5-3 shows the proposed layout of the landfill site.

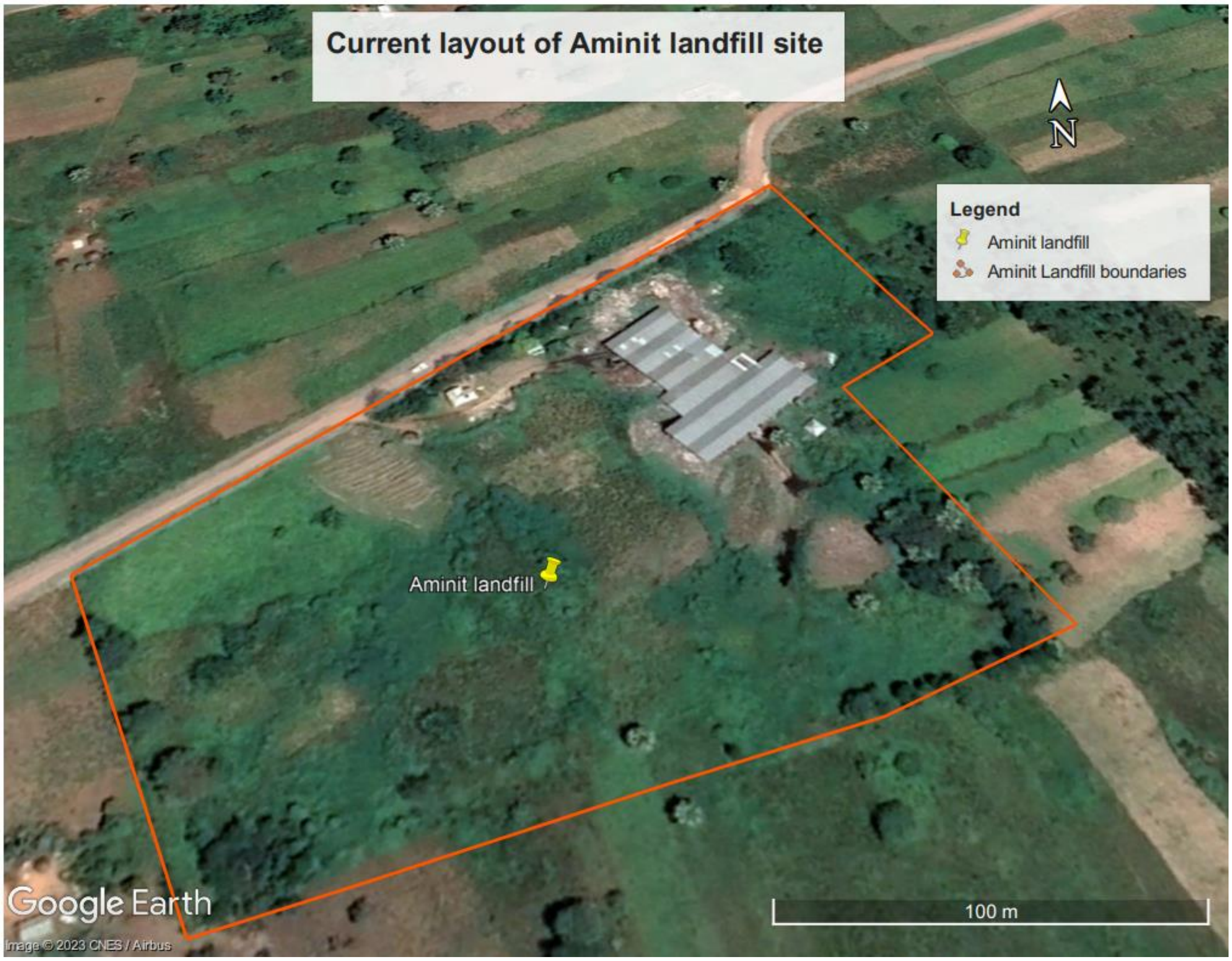

Figure 5-2: Current state of Aminit landfill site

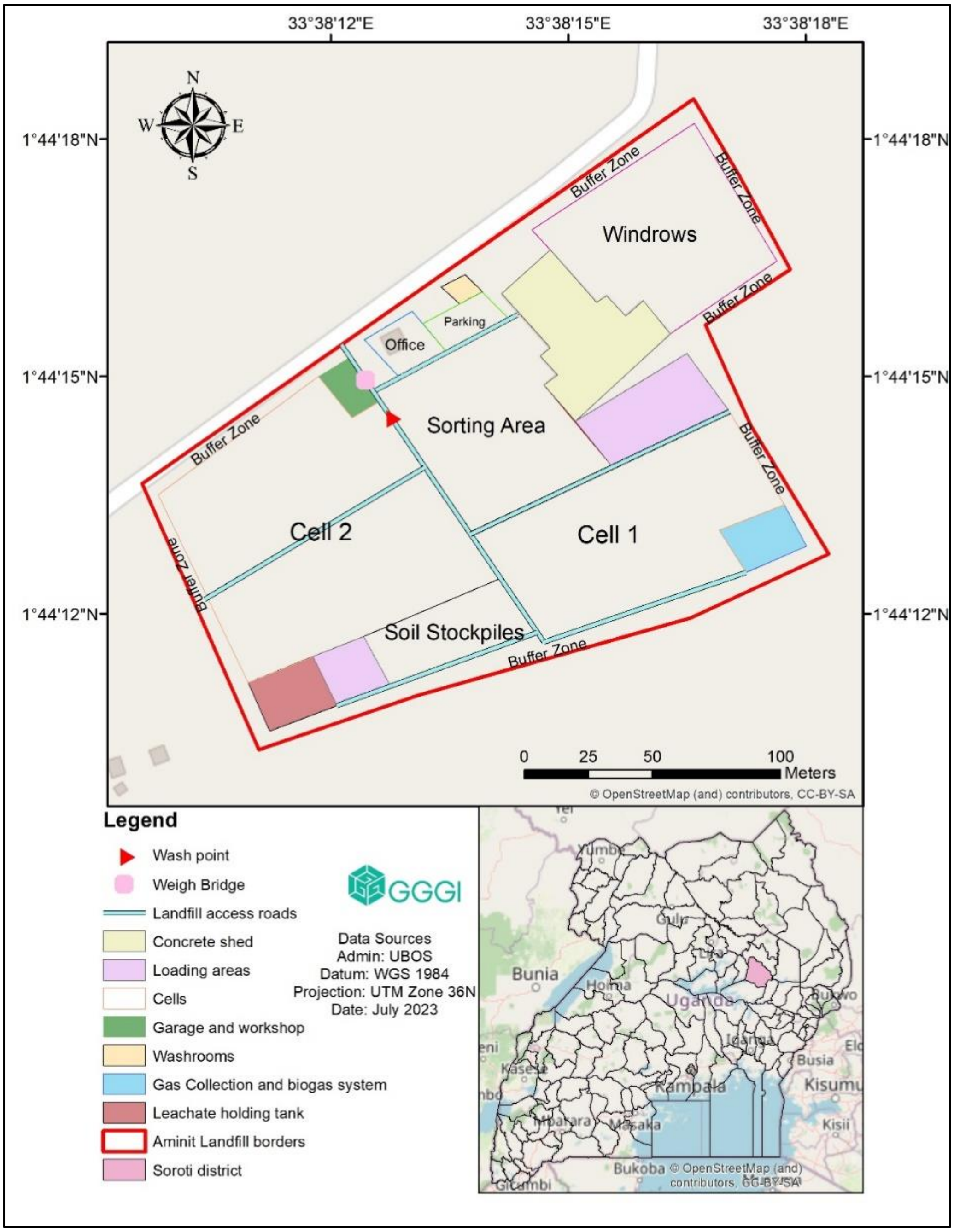

Figure 5-3: Proposed site layout of the Aminit landfill

A variety of solid waste management techniques have been reviewed for their suitability to be adopted for management of solid waste that has not been valorized. Some of these options include composting, landfilling, incineration and anaerobic digestion. The feasibility of the different potential options for the industrial park is assessed below;

Composting: Composting is already taking place at the Aminit landfill site. The market for the manure obtained from this process is readily available. Some of the infrastructure required for this process is also available for example a concrete shed, wheel loader, sieves for grading manure. There will also be enough waste from the industrial park after consideration of valorization and the general public to meet the demands for composting.

Incineration: A small incineration plant maybe required for the disposal of hazardous waste especially that coming from the manufacture of herbal medicines. Hazardous waste can neither be landfilled nor used for energy recovery hence acquisition of an incinerator for this purpose is recommended.

Landfilling: Aminit landfill is located about 5km away from the industrial park. The portion of land available for landfilling can take up waste up to two years (**Error! Reference source not found.**). The landfill site is however yet to be fully developed. The landfill can also be easily accessed as the distance between the two is not tedious.

Anaerobic Digestion: Feedstock for biogas production includes organic waste which will not be valorized. This waste should have high water contents, low structure and low lignin (Körner et al., 2006). Some examples of this type of waste include food wastes from hotels and domestic workers in the industrial park. Most of these sources are scattered around the park which may make it hard to carry out these processes and also most of the solid waste from the industrial processes is high in lignin making it less suitable for digestion (shells, seeds).

The criteria shown in Table 5-6 was followed for choosing the best option for management of solid waste disposal at the Soroti Industrial and business park.

Table 5-6: multi-criteria analysis for identification of suitable solid waste management option

Criteria	Composting	Landfilling	Incineration	Anaerobic digestion
Capital cost	+	+	x	x
O & M costs	+	+	x	++
Material and energy recovery	x	+	×	++
Environmental impact	+	×	×	+
Acceptance	x	×	+	++
Local Labour Experience	+	++	+	+
Feasibility	++	++	+	+

Key: ++ Good +Fair x Bad

Based on the data presented in Table 5-6 and the assessment carried out, landfilling, incineration and composting are the proposed solid waste management options for solid waste that will not undergo valorization in the industrial park.

5.4.1 Composting

Composting is currently taking place at the Aminit landfill site, the solid waste received at the landfill is placed under the shed where it undergoes composting after which it is sieved to obtain manure of Grade A (fine particles) and Grade B. Some of the challenges faced during composting include lack of fuel in the wheel loader to move the material, uncontrolled leachate from the solid waste, leaking roof. Improvement of this process can be through provision of a gentle slope and channels of about 0.5m wide by 0.5m deep and approximately 250m to convey away the leachate generated to a lagoon, repair of the roof which is about 1900m^2 to avoid leakages, provision of at least ten (10) Personal Protective Equipment (PPE) for the workers at the site and carrying out routine maintenance of the plant and the equipment.

Windrows is the suggested method for composting at the plant and these will be designed in order of reducing size from active to maturation stages since the compost will be expected to reduce size with time. The organic waste in the active stage where decomposition initially takes place will be moisturized with recycled leachate and water in order to increase the moisture content of the waste. After the active stage which will be about 3-4 weeks, the compost will be shifted to the next windrow for the curing stage which takes 6-8 weeks. When maturation is attained, the compost will be sieved to separate the larger particles from the fine compost. The larger particles are taken back for re-composting or can be landfilled while the fine compost will be sold to the farmers with a kilogram of compost estimated at USD 0.04. **Error! Reference source not found.**Figure 5-4 showing the different steps entailed in the composting process.

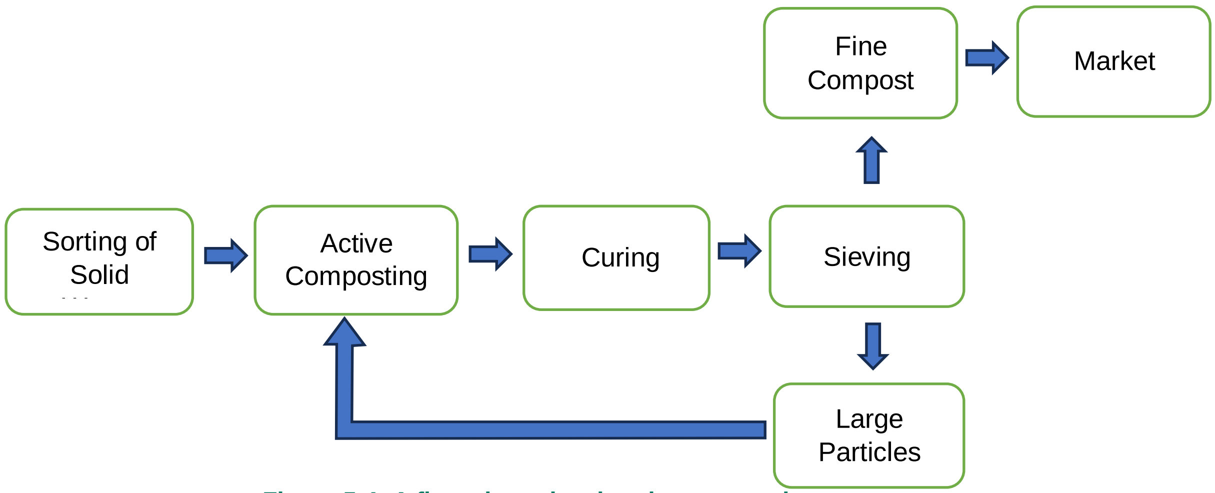

Figure 5-4: A flow chart showing the composting process

An estimate of the area required, dimensions of windrows and dimensions of the footprint area required for composting the monthly organic matter generated in the Soroti Industrial Park is shown in Table 5-7 below.

Table 5-7: Calculation of the estimated footprint area required for composting

Parameter	Units	Level of Development		
		35%	75%	100%
Height of Windrow	m	1.5	1.5	1.5
Length of Windrow	m	50.0	50.0	50.0
Width of windrow	m	3.0	3.0	3.0
Width of aisle	m	1.0	1.0	1.0
Volume of each windrow	m^3	148.5	148.5	148.5
Feedstock generated in 4 weeks	Kg	2,147,192.0	6,172,697.1	8,616,262.9
Volume of feedstock generated in 4 weeks	m^3	3,578.7	10,287.8	14,360.4
Number of windrows required	No	24.1	69.3	96.7
width of all windrows	m	72.3	207.8	290.1
Width of all aisles	m	24.1	69.3	96.7
Combined width of aisles, buffer area and windrows	m	98.4	279.1	388.8
Combined length buffer area and windrows	m	52.0	52.0	52.0
Required Pad footprint Area	m^2	5,116.5	14,513.9	20,218.3
Length of Pad	m	55.0	55.0	55.0
Width of Pad	m	93.0	263.9	367.6

The capital cost for the setting up the composting process was also estimated based on the estimated cost for the Mbale composting plant (Niwagaba et al., 2015.) as shown in Table 5-8 below.

Table 5-8: Estimated capital cost for setting up the composting process

Parameter	Level of Development		
	35%	75%	100%
Land Occupied (m^2)	5,116.5	14,513.9	20,218.3
Land Occupied (acres)	1.3	3.6	5.0
Amount (USD)	158,040.1	448,307.5	624,505.8

5.4.2 Landfilling

In landfilling, the incoming trucks delivering waste to the landfill will be weighed on the weigh bridge to accurately determine the waste received in order to come up with the different solid waste rates and for invoicing purposes. Improvement and expansion of access roads (about 600m) will be done to enable easy movement in the landfill area. The waste footprint area will also be divided into two (2) individual cells of about 2 acres each with a single cell constructed and filled at a time which will help reduce initial investment costs, minimizes soil stockpile expenses, reduces leachate generation, limits exposed waste areas and control litter, birds, and pests. Each cell will be lined at the base with liner material to prevent soil and groundwater contamination and to facilitate leachate collection and removal. The leachate will be collected through perforated pipes and delivered to a sump from where it will be pumped to a lagoon. The leachate expected to be generated from the solid waste was calculated according to Equation(1 (Choden *et al.*, 2022) where V is the monthly volume of leachate generated, R is the maximum monthly average rainfall sum from observed data (1981-2020) obtained as 175mm and A is the area of a cell.

$$V = R \times A \times 0.15 \quad (1)$$

The expected volume of leachate per month will be 212.45m^3 (7.1m^3/day) and a lagoon (about 300m^3) is proposed for the treatment of the generated leachate.

After waste disposal, mechanical compaction will be performed, followed by the daily covering of the waste surface and side slopes with a soil layer of at least twelve (12) centimeters. Trucks exiting the landfill will be washed or their tyres sprayed to prevent waste mud and contaminants from being transported onto public roads.

Landfills pose some threats to the environment which include contamination of ground and surface water by the leachate generated, emission of greenhouse gases (Methane and carbon dioxide). These can be minimized through the use of Leachate collection systems and gas collection systems respectively. Other environmental impacts include odor, dust, noise and air pollution. Landfills are also liable to fire breakouts, these will be controlled by the daily soil cover provided for after compaction of waste and collection of the gases produced at the landfill. Fire management equipment such as fire extinguishers will also be available at the proposed landfill office. A chain link fence of about 900m will also be provided to prevent scavengers and children from accessing the landfill. The Aminit dumpsite is the location suggested for these processes to take place. Figure 5-5 illustrates the process involved during landfilling.

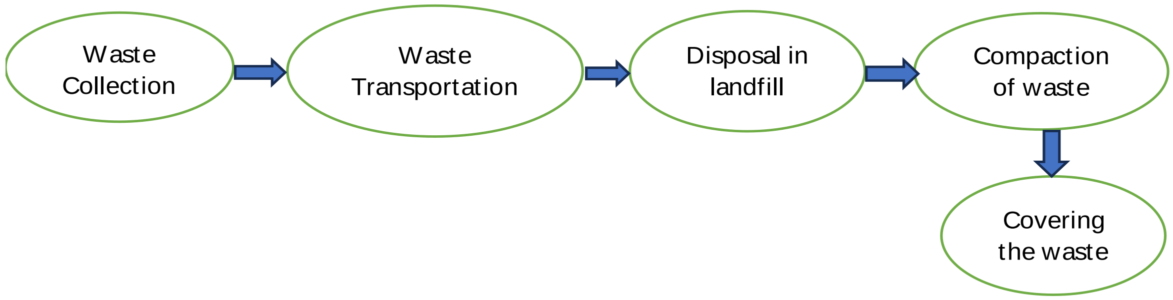

Figure 5-5: Flow chart showing the process of landfilling

An estimate of the total area required for the disposal of the annual waste generated in the Soroti Industrial Park after valorisation and composting have been done is shown in Table 5-9.

Table 5-9: Estimation of area required for landfilling the annual solid waste generated at the industrial park

Parameters	Level of Development		
	35%	75%	100%
Projected Annual Waste Generation (tonnes)	732.1	1,568.8	2,091.7
Volume of the waste (m^3)	861.3	1,845.6	2,460.8
Total Volume of annual Daily Cover (m^3)	86.1	184.6	246.1
Total volume for liner system and caps (m^3)	215.3	461.4	615.2
Volume due to settlement in (m^3)	86.1	184.6	246.1
Capacity of landfill (m^3)	1,076.6	2,307.0	3,076.1
Average landfill height (m)	5.0	5.0	5.0
Area for landfilling(m^2)	215.3	461.4	615.2
Area of Site (m^2)	36,988.20	36,988.20	36,988.20

5.4.3 Incineration

The incineration process will be done for the hazardous waste generated from the herbal medicine sector and this will involve the preparation of the waste depending on the physical characteristics of the waste. The waste will then be put in the combustion chamber where carbon dioxide, water vapor and ash residue will be generated. Air pollution will be the main environmental threat from incineration, and this could be controlled by employing air control equipment such as quench, venturi scrubber, Wet scrubber and other equipment (Oppelt, 1987). The ash residue generated will be taken to the Aminit landfill. The estimated retail price of an incinerator for an organization which produces substantial waste is about USD 12,300. The figure below shows the process followed for incineration of solid waste.

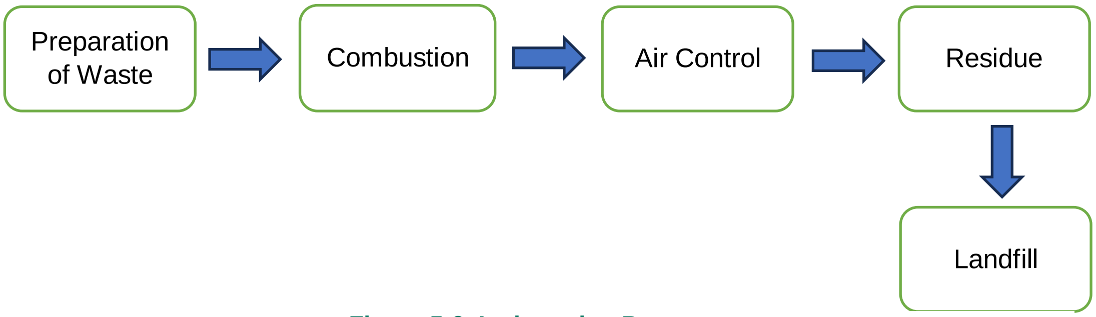

Figure 5-6: Incineration Process

Finally, the consultant recommends that all solid waste that will not be valorized be taken to the Aminit landfill where different processes like sorting for recyclables and composting will take place. Incineration of hazardous waste from the herbal medicine sector will be done on site of generation and the ash later taken to Aminit landfill.

5.5 Solid Waste Management Strategy

The solid waste management strategy incorporates the valorization of solid waste into new products as the priority option. This will be followed by composting of the organic waste not subjected to valorization and finally landfilling of the inorganic waste.

The strategy aims at creating a greening process through reduction of the greenhouse gases generated. The global warming of landfills potential is especially high for methane gas which has 21% more potential than carbon dioxide to cause global warming (Ramprasad et al., 2022). Projections of methane emissions for the business-as-usual scenario and the proposed strategy were done using the IPCC Waste Model and Guidelines (IPCC, 2007). The projections indicated that the methane emissions will be reduced by about 1431Gg of methane over a period of 30 years if the proposed strategy is taken up.

6. Stormwater Management

6.1 Hydrological Studies

Comprehensive hydrological studies were carried out to identify and determine the catchment area and estimate the design flows for the appropriate return periods for the catchment of the Soroti IBP.

6.1.1 Design Return Period

The choice of the re-occurrence of the flood magnitude was guided by the following factors:

i) Amount of traffic and expected level of service
ii) Potential flood hazard to property
iii) Magnitude and risk associated with damages from larger flood events
iv) Conditions for practical detour during probable failure

In addition, other factors like; potential upstream land use for the anticipated life of the possible drainage structures and construction cost were also considered in selection of the design return periods.
The design return periods shown in **Table 6-1**, based on geometric design criteria, were used for planning, design and analysis (MoWT, 2010).

Table 6-1: Design Return Period for Structure Types by Geometric Design Criteria

Structure Type	Geometric Design Standard			
	PIa, PIb	PIII Gravel A	PIII, Gravel B	Gravel C
Gutters and Inlets*	10/5	2	2	-
Side Ditches	10	10	5	5
Ford/Low-Water Bridge	-	-	-	5
Culvert, pipe (See Note) Span < 2m	25	10	5	5
Culvert, 2m < span < 6m	50	25	10	10
Short Span Bridges 6m < span < 15m	50	25	25	25
Medium Span Bridges 15m < span < 50m	100	50	50	50
Long Span Bridges spans > 50m	100	100	100	100
Check/Review Flood	200	200	100	100
PIa = Paved Ia PIb = Paved Ib PII = Paved II PIII = Paved III				

Note: The span in the above table is the total clear opening length of the structure. For example, the span of a double 1.2 m diameter pipe is 2.4 m.

6.1.2 Estimation of Rainfall Intensities

6.1.2.1 Analysis of Recorded Rainfall time series

Daily rainfall data obtained from the nearest rain gauge station to the project area which has adequate years of rainfall time series is detailed in **Table 6-2**.

Table 6-2: Rain gauge Station in close proximity to the site

Rain gauge Station	No. of rainfall recorded years	Start year	End year
Soroti Met. Station	40	1981	2020

Soroti Meteorological station data was used for the analysis due to its close proximity to the Soroti IBP as well as having a long (39 years) rainfall time series of adequate data. The maximum 24-hour rainfall recorded during the period of record is 148.1 mm and was recorded on 3rd October 2001.

6.1.3 Rainfall Intensity Duration Frequency (IDF) relationships

Using the Annual Maximum Series (AMS) method (Butler and Davis, 2011), the annual maximum daily rainfall depths were abstracted from the observed daily rainfall time series. The annual maximum values were then ranked from 1 to x in order of decreasing magnitude.

Weibull plotting position formula was applied to estimate the rainfall return periods.

$$T = \frac{(x+1)}{n} \qquad \text{Equation 2}$$

Where;
T is the return period and,
n is the rank.

The above method was applied to estimate the rainfall with low returns as shown in **Figure 6-1**.

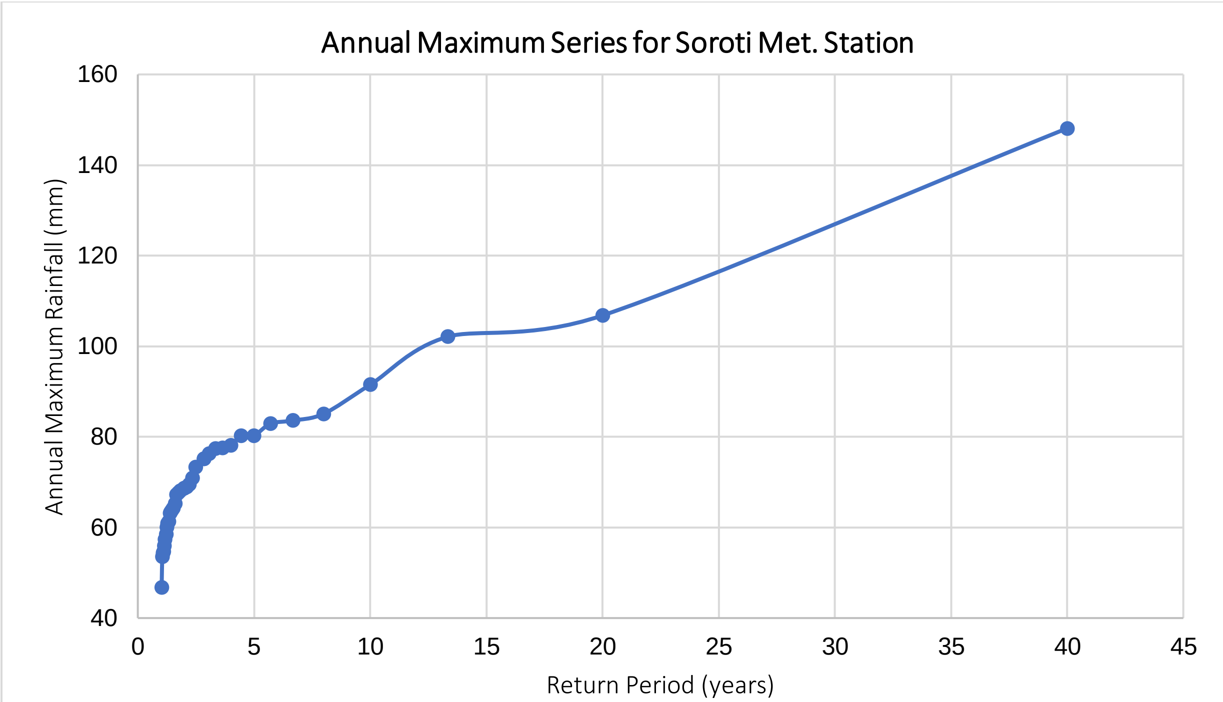

Figure 6-1: Derived Annual Maximum Rainfall time series for Soroti Meteorological station

In this study, the 2-yr 24-hour rainfall value for Soroti Met. Station was determined from the graph above as **68.6 mm** and considered for further analysis.

6.1.3.1 Impact of Climate Change on Daily Maximum Rainfall

According to the 4th Intergovernmental Panel on Climate Change Assessment Report, the global climate change models project an increase in average temperatures in Uganda by up to 1.5ºC in the next 20 years and by up to 4.3ºC by the 2080's. In addition, the report predicts an increase in rainfall and corresponding run-off volumes of 10 – 20% over most of the country (UN-Habitat, 2009).
In this study, all hydrological studies and hydraulics designs for the project took into consideration a climate change factor of 1.2 (Mugume et al., 2013). This climate change factor was applied to the 2 yr 24-hour rainfall to account for the effect of climate change on rainfall extremes. The 24-hour rainfall depths estimated for higher return periods are shown in **Table 6-3**.

Table 6-3: 24-hour Rainfall Depths at Soroti IBP

Rainfall Return Period, T	10	25	50	100	200
Flood Factor	1.52	1.81	1.90	2.09	2.47
Index 'n'	0.96	0.96	0.96	0.96	0.96
24 hr Rainfall Depth (mm)	125.13	149.00	156.4	172.05	203.33

6.1.4 Catchment Delineation

Catchment delineation refers to the process of creating a boundary that represents the contributing area for a particular control point or outlet. The process of catchment delineation is used to define boundaries of the study area and/or to divide the study area into sub-areas. In this work, the Digital Elevation Model (DEM) based automatic catchment delineation was undertaken in ArcGIS software, using the ArcHYDRO Extension. The input data into ArcGIS was a SRTM DEM. The DEM has a horizontal resolution of 30 m and was downloaded from United States Geological Survey (USGS) data. The delineated catchment for

Soroti Industrial and Business Park covers an area of 12.96 km² with an average slope of 3.75%. **Figure 6-2** below shows the delineated catchment for Soroti IBP.

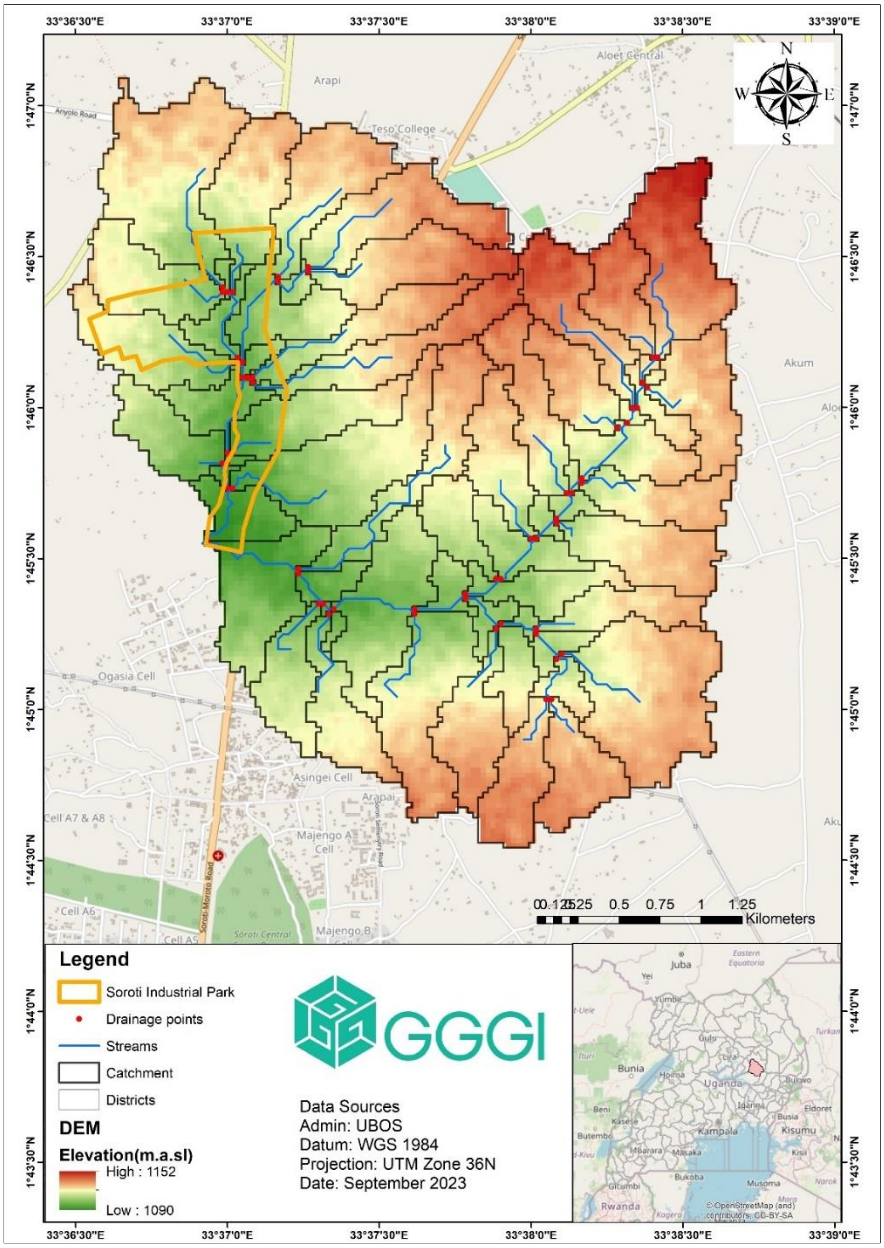

Figure 6-2: Delineated Catchment for Soroti Industrial and Business Park showing sub catchments and streams overlain a Digital Elevation Model

6.1.5 Estimation of Design Peak Flows

6.1.5.1 Choice of flood flow estimation methods

Having chosen the design return periods, peak design flows were estimated using hydrologic parameters of the catchment area using the most appropriate methods for flood flow estimation for an ungauged catchment. Various methods for flood flow estimation were evaluated in detail and the most context appropriate ones chosen. **Table 6-4** shows the comparison of the various methods for flow estimation.

Table 6-4: Comparison of various design flood flow estimation methods

Pros	Cons
TRRL East African Flood Model	
• Provides a simple and straightforward method for predicting design storms for flood estimation in East Africa. • Based on extensive field and desktop analytical studies in East Africa	• Suitable for catchments < 200 km^2
Modified Rational Method	
• Simple and straight forward rainfall intensity-based run-off estimation method • Suitable for catchments with limited data • Provides an estimation of the maximum flows from a catchment • Accounts for the effect of storage on flood wave attenuation for large catchments	• Uses a constant rainfall intensity which is not appropriate for long duration time series • Inaccuracies in estimation of the composite run-off coefficient which is dependent on various factors e.g., soil moisture content, rainfall intensity and duration, degree of soil compaction, vegetation etc.
Soil Conservation Service (SCS) Method	
• Widely used dimensionless Unit Hydrograph method • Simple and straight forward method	• Key parameter such as the ratio of time to peak to the base time not satisfactorily applicable to East African Catchments • Applicable to small ungauged urban catchments

In this study, the TRRL Method was chosen and applied for the flood estimation.

6.1.5.2 Estimation of design peak flows using the TRRL Method

The Transport and Road Research Laboratory (TRRL) method that was developed for Uganda, Kenya and Tanzania made use of limited data for flood estimation for highway bridges and culverts. The model is used for estimating flows for catchments less than 200 km^2.

The TRRL method combines catchment parameters such as catchment area and slope, length of the main stream, land cover and channel slope together with other parameters such as Standard Contributing area coefficient, Catchment wetness factor, catchment lag time and contributing area coefficient to predict the peak flow and base time of design hydrographs for catchments.

The TRRL Method (Fiddes et al., 1974) involves the following main steps

i) Determination of time of concentration
ii) Design rainfall estimation

iii) Estimation of rainfall excess
iv) Estimation of run-off

The detailed description of the TRRL method is found in section 5.3 of the Ministry of Works and Transport (MoWT) Drainage Design Manual (2010), Volume 2 and Chapter 4 of the TRRL Laboratory report 706 (Fiddes et al, 1976). The results in **Table 6-5** below indicates the design peak flow for the Soroti IBP catchment for the estimated return periods.

Table 6-5: Design Flood Estimates obtained using the TRRL Method for the Soroti IBP Catchment

Parameter	T = 5 yrs.	T = 10 yrs.	T = 50 yrs.	Remarks
Catchment Area, A (km^2)	13.0	13.0	13.0	
Land Slope, S_L (-)	0.0375	0.0375	0.0375	
Length of main stream (km)	4.6700	4.6700	4.6700	
Channel Slope (-)	0.0096	0.0096	0.0096	
Initial retention, Y (mm)	0.0	0.0	0.0	
Standard Contributing Area Coefficient, C_s	0.09	0.09	0.09	Moderate (Catchment slope 1-4%), well drained and friable of the ferrallitic type (sandy sediments and sandy loams) (0.09)
Catchment Wetness Factor, C_W	1.0	1.0	1.0	Semi-Arid Zone: Ephemeral Streams
Land Use Factor, C_L	0.5	0.5	0.5	Grass cover, Ephemeral stream, sand filled valley, swamp filled valley, Forest
Contributing Area Coefficient, C_A (km^2)	0.049	0.049	0.049	
Catchment Lag Time, K (hrs.)	8.167	8.167	8.167	Papyrus swamp in valley bottom, good pasture, cultivated land
Rainfall Time, T_P (hrs.)	0.750	0.750	0.750	
Initial Flood Wave Attenuation Time, T_A (hrs.)	0.000	0.000	0.00	
Base Time, T_B (hrs.)	19.533	19.533	19.533	
T yr. 24 hr. rainfall for Soroti (mm)	99.6	125.1	156.4	Climate Change factor of 1.2 applied to the 2 yr. rainfall
Rainfall during base time, R_{TB}	98.5	123.7	154.7	
Areal Reduction Factor	1.00	1.00	1.00	
Average Rainfall, P (mm)	98.5	123.7	154.7	
Total Volume of Runoff, RO (m^3)	62038.8	77933.1	97416.3	
Average flow, Q_{avg} (m^3/s)	**0.8**	**1.0**	**1.3**	
		2nd iteration		
Flood Wave Attenuation Time, T_{A1} (hrs.)	0.01349	0.01274	0.01205	
Base Time, T_B (hrs.)	19.547	19.546	19.545	
Rainfall during base time, R_{TB}	98.501	123.736	154.670	
Average Rainfall, P (mm)	98.5	123.7	154.7	
Total Volume of Runoff, RO (m^3)	62,041	77,936	97,420	
Average flow, Q_{avg} (m^3/s)	**0.8**	**1.0**	**1.3**	
		3rd iteration		
Flood Wave Attenuation Time, T_{A1} (hrs.)	0.01349	0.01274	0.01205	
Base Time, T_B (hrs.)	19.547	19.546	19.545	
Rainfall during base time, R_{TB}	98.501	123.736	154.670	
Average Rainfall, P (mm)	98.5	123.7	154.7	
Total Volume of Runoff, RO (m^3)	62,041	77,936	97,420	
Average flow, Q_{avg} (m^3/s)	**0.8**	**1.0**	**1.3**	
Peak flow, Q_T	**1.9**	**2.4**	**3.0**	**For K > 1 hr., F = 2.3**

Therefore, the chosen 50-year, 100-year and 200-year design peak flows are **3.0 m^3/s, 3.3 m^3/s** and **3.9 m^3/s** respectively.

6.1.6 Stormwater Drainage System Layout

The existing drainage system around the Soroti IBP is located around the Soroti Fruit Factory property with the two outfalls, draining into the swamp, located at coordinates 0° 46'29.89"N, 33°37'1.33"E and 0° 46'18.31"N, 33°37'2.30"E as shown in **Figure 6-3** and **Figure 6-4**.

Figure 6-3: Stormwater Drainage System Layout around Soroti Fruit Factory overlain a Google earth image

6.1.7 Hydrological Design of Drainage Channels

Hydrological studies were undertaken for the drainage system in order to compute the design flows capacities of each drainage channel.

6.1.7.1 Estimation of Design Peak Flows using Modified Rational Method

The peak discharge from the contributing catchment was estimated using the Modified Rational Method as shown in **Table 6-6** below, considering 5-yr and 10-yr return periods.

The rational method is a simple technique developed by Kuichling (1889) for estimating design peak runoff for areas up to 640 acres (Ohio Department of Transportation, 2014). The rational method is based on a formula that relates runoff-producing potential of the watershed, the average intensity of rainfall for a particular length of time (time of concentration) and the catchment area (Thompson, 2006).
This method is mainly based on the following assumptions:

- Peak flow occurs when the entire catchment is contributing
- Rainfall intensity is uniform over the entire catchment area
- Rainfall intensity is uniform over a duration of time equal to or greater than the time of concentration
- Rational coefficients are independent of the intensity of the rainfall
- The return period of the run-off is assumed to match with the return period of the rainfall

The rational equation is expressed as follows:

$$Q = C_f \times \frac{CiA}{360} \qquad \text{Equation 3}$$

Where:
Q is the peak discharge (m^3s^{-1})
C is the runoff coefficient (dimensionless)
i is the design rainfall intensity (mm/hr)
A is the catchment area (ha)
C_f is the multiplier of higher recurrence intervals (dimensionless)

Runoff coefficient, C

The runoff coefficient, C, is a dimensionless ratio of rainfall excess to total rainfall and it varies with the topography, land use and surface characteristics of the drainage area. **Table 6-6** shows typical values of runoff coefficients, C for urban areas.

Table 6-6: Typical values of runoff coefficients for urban areas

Land Use	Condition	Range of C values
Lawns	Sandy soil, flat <2%	0.05-0.10
	Sandy soil, steep >7%	0.15-0.20
	Heavy soil, steep <2%	0.13-0.17
	Heavy soil, steep >7%	0.25-0.35
Residential	Single Family areas	0.30-0.50
	Apartment dwelling areas	0.50-0.70
Industrial	Light areas	0.50-0.80
	Heavy areas	0.60-0.90
Business	Downtown areas	0.70-0.95
	Neighbourhood areas	0.50-0.70
Streets	Asphaltic	0.70-0.95
	Concrete	0.80-0.95
	Bricks	0.70-0.85
Roofs		0.75-0.95

A higher value of **0.9** has been adopted so as to take into consideration the post development run-off resulting from anticipated future land use and land cover changes in the catchment area.

Time of concentration

The time of concentration is the time required for water to flow from the most remote point on the watershed boundary to the point of interest. When using the rational method, it was assumed that peak flow occurs because of surface runoff accumulating over a duration equal to the time of concentration.
The time of concentration was estimated using the SCS overland sheet flow equation.

Design rainfall intensity, i

The design rainfall intensity, *i*, is the average rate of rainfall (mm/hr) for a duration equal to the time of concentration. One of the main assumptions of the rational method is that the return period of a computed peak flow is the same as that of the rainfall intensity.

The relation between rainfall duration, rainfall intensity and the return periods is represented by Intensity-Duration-Frequency (IDF) curves. The IDF curves are determined by analysis of rainfall data for a particular site or by the use of standard meteorological atlases (Thompson, 2006). Once the return period has been selected for the design and a time of concentration calculated for the catchment, the rainfall intensity can be determined from the IDF curves approximated using the standard formula below;

$$i = \frac{a}{(t_c + b)^c} \qquad \text{Equation 4}$$

Where:
i is the design rainfall intensity (mm/h)
t_c is the time of concentration (h)
a, b and c are constants depending on the region/location of the catchment.

Figure 6-4 shows the stormwater drainage layout around Soroti Fruit Factory overlain a satellite image showing the drainage channels.

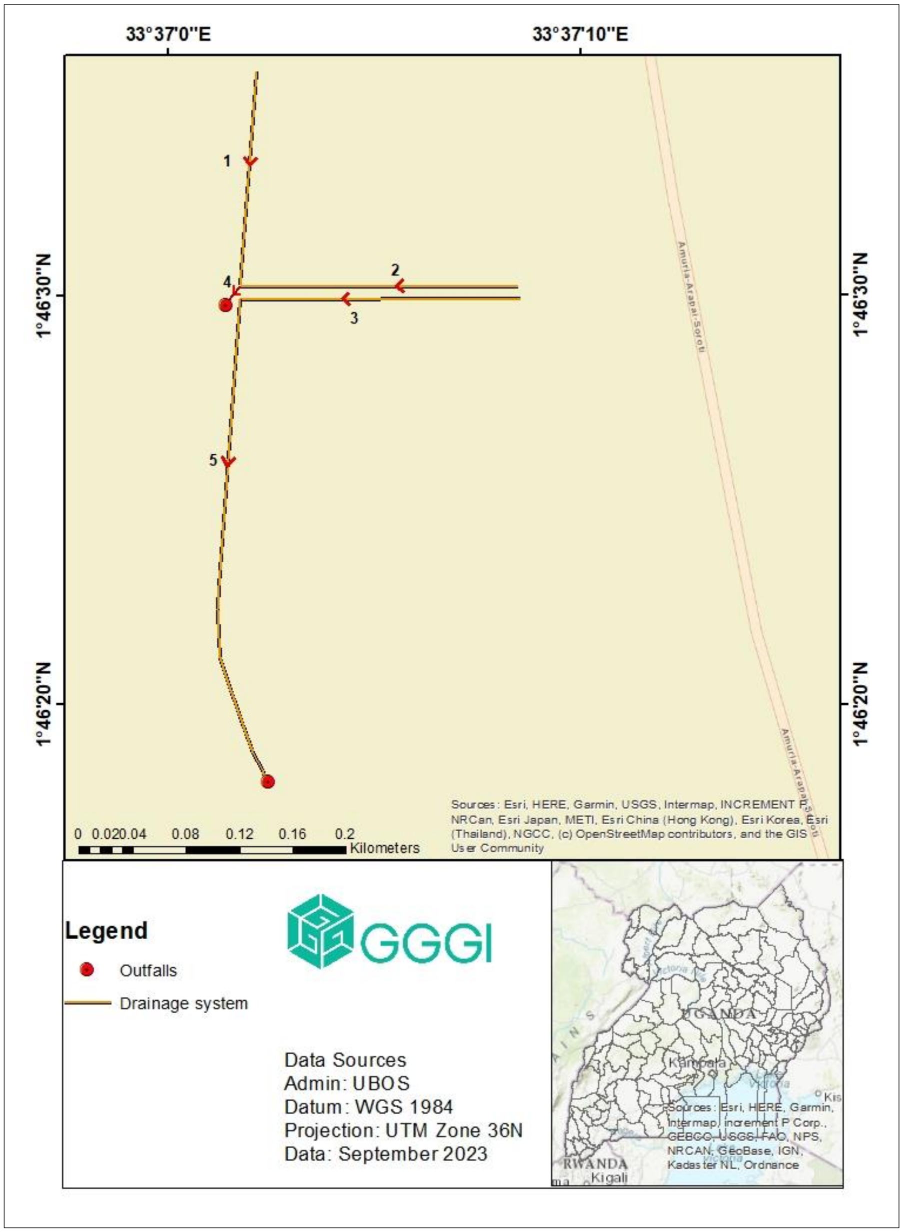

Figure 6-4: Stormwater Drainage System Layout around Soroti Fruit Factory overlain a satellite image

Table 6-7 shows the computed design flows for the drainage channels using the Modified Rational Method.

Table 6-7: Computed Design Flows for the drainage channels using the Modified Rational Method

Channel	Catchment Area (km^2)	Catchment Area (ha)	Length of main stream (km)	Average slope of Catchment (%)	Time of concentration, T_c (hrs)	Rainfall Intensity (mm/hr) 5 yr	Rainfall Intensity (mm/hr) 10 yr	Rational Coefficient	Peak Reduction Factor	Design Flow, Q (m^3/s)	
										5 yr	10 yr
1	0.0014	0.14	0.161	3.75	0.06	218.97	277.4	0.70	1.00	**0.06**	**0.07**
2	0.218	21.76	0.838	3.75	0.20	160.74	203.6	0.70	1.00	**6.80**	**8.61**
3	0.002	0.20	0.010	3.75	0.01	250.76	317.6	0.70	1.00	**0.10**	**0.12**
5	0.031	3.12	0.382	3.75	0.11	196.51	248.9	0.70	1.00	**1.19**	**1.51**

6.1.8 Blue Green Infrastructure for Stormwater Management

6.1.8.1 Rainwater Harvesting Tanks

Rainwater harvesting involves the gathering and retention of stormwater for on-site reuse, typically through the capture of runoff from building rooftops. These collection structures come in diverse forms and can be installed either above ground or below the surface. Depending on its source and treatment, harvested rainwater can serve various purposes, including industrial cooling processes.

Given the paved nature of the Soroti fruit factory, substantial runoff is generated following storm events, estimated at 20.1m^3/s. The Consultant undertook preliminary studies to determine the capacity of rainwater tanks required for the Industrial Park and they are detailed in the proceeding section. This measure would consequently reduce effective runoff from the site, thereby mitigating peak flood occurrences.

6.1.8.1.1 Estimation of rainwater harvesting tanks

The computation of the approximate volume of rainwater tanks was done using BS 8515:2009 – the British Standard for designing rainwater harvesting tanks. The intermediate approach was followed in the design and this method takes the lower of 5% of the annual rainwater yield or 5% of the annual non-potable water demand.
The annual average rainfall was determined from analysis of the daily rainfall values from Soroti Met Station and input into the equation shown below.

$$Y_R = A \times e \times AAR \times \eta \times 0.05$$

Where
Y_R is 5% of the annual rainwater yield
A is the collecting area (m^2)
e is the yield coefficient (%)
AAR is the depth of the annual average rainfall for the location (mm)
ŋ is the hydraulic filter efficiency

Table 6-8: Computation of the rainwater harvesting volume

Description	Value
Average Annual Rainfall (mm)	1334.2
Roof Plan Area (m^2)	88706.8
Yield Coefficient (%)	90
Hydraulic Filter efficiency (%)	90
Rainwater yield (l)	4793401.1
Rainwater yield (m^3)	**4793.4**

The annual non-domestic demand was estimated from Chapter 3 of the report as 16,490 m^3/d.

Table 6-9: Annual Industrial Demand

Description	Value
Industrial Demand at 100% development (m^3/d)	16490
Annual Water Demand (m^3)	6018850
5% of annual demand (l)	300942500

The required volume of rainwater tanks was estimated to be 4,793.4 m3. This volume is less than 5% of the annual non-domestic demand. The final adopted volume for the rainwater tanks is 5,000 m3.

The required volume of rainwater tanks will lead to a reduction in annual water bills of 1.6% which corresponds to approximately UGX 239,670,053 savings annually. This consequently lowers the energy demand for pumping by 1.56% since this demand is met by the rainwater tanks.
Additionally, rainwater tanks will reduce peak runoff generated from the catchment by 0.7% while reducing the peak runoff generated from the industrial park by approximately 10%.

6.1.8.2 Detention ponds

Detention ponds are engineered or naturally created depressions which serve the crucial function of temporarily storing and gradually releasing stormwater runoff. Their benefits encompass peak flow reduction, which significantly mitigates the risk of downstream flooding and erosion and also safeguard both infrastructure and the local environment. They also act as efficient sediment traps, allowing particulate pollutants to settle out of the runoff before discharge, thereby enhancing water quality—an essential consideration for an industrial facility like Soroti Fruit Factory.

In comparison to traditional drainage systems, detention ponds tend to require less maintenance and provide multiple benefits beyond runoff control. To ensure their effectiveness, it is imperative to determine the appropriate size of the pond based on site-specific factors and the desired reduction in peak runoff. The adoption of detention ponds as part of a blue-green infrastructure strategy will not only addresses Soroti Fruit Factory's immediate runoff challenges but also align with principles of environmental sustainability and modern regulatory standards, positioning the factory as an environmentally responsible operation.

The size of the detention pond was estimated basing on the water quality volume method shown in the equations below.

$$R_v = 0.05 + 0.009(l)$$

$$WQ_v = \frac{1.5R_vA}{12}$$

Where
I is the percentage of impervious cover
WQv is the water quality protection volume (acre-feet)
Rv is the volumetric runoff coefficient
A is the total drainage area (m)

Table 6-10: Preliminary design of the detention pond

Description	Value
I (%)	90
Rv	0.0581
A (acres)	3,202.49
WQv (m^3)	28,682.35

The required volume of the detention pond was determined as approximately 30,000 m^3.

Currently, the swamp downstream is the natural outfall of all the water released from the Industrial Park as well as the upstream catchment. However, there have been illegal brick mining activities within the swamp. This activity degrades the swamp and could affect the natural balance of the ecosystem. The swamp retains water which undergoes natural processes of treatment before it is released further into the downstream catchment and brick making could contaminate the water. A detention pond prevents flooding downstream in the swamp by temporarily retaining water after a storm event.

7. Conclusions

7.1 Water and Sanitation Infrastructure at the Soroti BIP

The proposed water and sanitation infrastructure at the Soroti Business Industrial Park is presented below.

7.1.1 Water Supply

Construction of six water storage tanks of approximately 500 m^3 capacity using pressed steel panels erected on steel towers to increase the residual head for the end-point users. The storage reservoir tanks will be supplied by approximately 7.58 km of the distribution pipeline from the Soroti Rock. In addition, a total of approximately 3.1 km of distribution trunk mains are required to distribute the water from the reservoir to the different units at the industrial park. Furthermore, approximately 25 No. 4''x4'' double fire hydrants are will be installed along the main access roads at 100 m spacing to manage the risk of fire outbreak at the park. The fire hydrants will be supplied from an independent reservoir of capacity 150m^3. Two parallel water treatment units of capacity 8,500 m^3/day will be constructed to meet the mid-term and long-term water demand at the industrial park. This will also consist of 16 km transmission mains from the treatment plant to the reservoirs at Soroti Rock and an additional 7.85 km distribution pipe to the reservoirs at the park.

7.1.2 Wastewater

Construction of approximately 12km long sewer lines and an industrial wastewater treatment plant with a capacity of 23,200 m^3/d. The final unit of the treatment plant will consist of activated carbon to remove inorganic pollutants before effluent is released to the environment

7.1.3 Solid Waste

The proposed solid waste management infrastructure includes valorisation to produce essential oils, butter, animal feeds and biochar from waste generated from the cassava sector. The rest of the solid waste will be processed at the Atara solid waste management facility where 8,186 tons of compost will be produced per month, inorganics recycled and the rest landfilled. Two landfill cells of about 2 acres each will be constructed at the Aminit dumpsite lined with synthetic material at the bottom.

7.1.4 Stormwater

The proposed stormwater infrastructure includes the construction of approximately 12km m of on-site grass-lined or stone-pitched drainage channels; and the construction of approximately 10,000 m^3 rainwater harvesting tanks to capture 10-year runoff from roofs. A detention pond of approximately 30,000 m^3 will be constructed to temporarily store runoff from peak flow events.

7.2 Proposed greening options for water and sanitation infrastructure

The proposed greening options have been considered in the detailed water and sanitation assessment for the Soroti BIP. Specifically, the following greening options have been considered:

i. Water Supply: Rainwater harvesting by different industries from their respective roofs at the park, use of solar power system as a replacement for diesel generators to power water pumps at the site in case of hydropower outage.
ii. Wastewater: Provision of activated carbon in the constructed wetlands will ensure good quality of the effluent.
iii. Solid waste: Composting of organic waste generated at the park to reduce the area required for the landfill and greenhouse gas emissions, waste valorisation to produce animal feeds, essential oils, and biochar, constructing lagoons for treating leachate to reduce pollution of water resources.
iv. Stormwater: Rainwater harvesting for non-potable uses and construction of a detention pond to temporarily store runoff and reduce peak flows.

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