SFD Report

Blantyre
Malawi

Final Report

This SFD Report – Level 1 - was prepared by the WASHTED Centre at the University of Malawi, The Polytechnic.

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SFD Report Blantyre, Malawi 2018

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This Executive Summary and SFD Report are available from:

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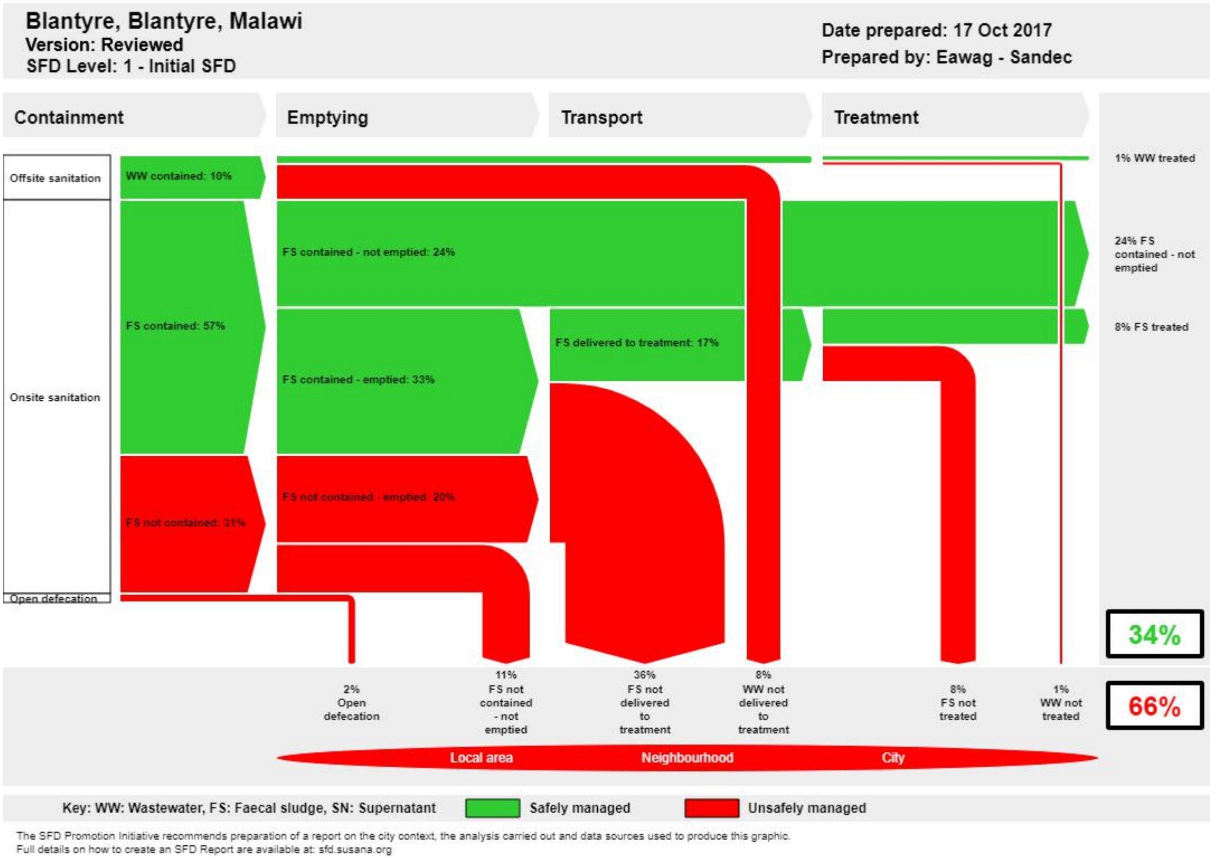
1. The SFD Graphic



2. Diagram information

SFD Level:

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The Shit Flow Diagram (SFD) was developed by the WASHTED (Water, Sanitation, Health and Appropriate Technology Development) Centre at the University of Malawi, The Polytechnic.

Collaborating partners

Water for People, WASTE Advisers Malawi (WAM) and Blantyre City Council (BCC)

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3. General city information

The city of Blantyre is the commercial and financial centre of Malawi and is located around 300 kilometres south-east of the capital, Lilongwe. Blantyre is situated at an altitude of approximately 1,050 meters above the sea level with a population of 1,068,681. The city of Blantyre itself is divided into 23 wards that each has a counsellor at the Blantyre City Council, itself headed by the Mayor. Over 65 percent of the city's population live in unplanned, informal settlements that are expanding quickly (UN-Habitat, 2011).

4. Service outcomes

The Blantyre City Council is responsible for wastewater treatment and solid waste management in the city though private pit emptiers are de-facto in charge of servicing informal areas (UN-Habitat, 2011; Palamuleni 2002). The most common technology used by pit emptiers is the Gulper, which was introduced by Water for People in 2012. Only one of the 5 treatment plants is operational; similarly, only one treatment plant accepts faecal sludge though illegal discharging is common (Republic of Malawi, 2007).

5. Service delivery context

Though numerous policies exist, and the country has an ambitious plan to provide sanitation for all by 2020, a small tax base and conflicting responsibilities mean that there is little maintenance or enforcement. An active NGO sector continues to work with and support various initiatives such as the Pit Emptiers Association, public toilets, and upcoming transfer stations and decentralized faecal sludge treatment.

6. Overview of stakeholders

At the national level, the Ministry of Health (MoH) is responsible for health in Malawi. Also at the national level, The Ministry of Agriculture, Irrigation and Water Development is responsible for water supply and sanitation services. The Blantyre City Council (BCC) is mandated by the Local Government Act and the National Sanitation Policy to manage the city's wastewater (Table 1). The BCC operates five wastewater treatment plants in Blantyre Operations are supported by city rates (property tax) and by fees levied on faecal sludge dumping at the wastewater plants. The Pit Emptiers Association (PEA) is a formal network of sanitation entrepreneurs who provide sanitation solution to households and institutions.

Table 1. Key stakeholders

Key Stakeholders	Institutions / Organizations /
Public Institutions	Blantyre City Council Ministry of Water Ministry of Agriculture, Irrigation and Water Development
Non-governmental Organizations	Water for People,Waste Advisors
Private Sector	Pit Emptiers Association Private Emptiers, toilet constructors, etc
Development Partners, Donors	Bill and Melinda Gates Foundation DFID
Others	WASHTED @ University of Malawi, the Polytechnic

7. Process of SFD development

The lack of surveys focused on the presence of infrastructure and reliable treatment measurements, led to significant uncertainties and most values were estimated based on proxy information and stakeholders' expert knowledge. The fast and uncontrolled urbanization as well as population growth in Blantyre means that information dates quickly and is unreliable.

8. Credibility of data

Given the simplicity of the sanitation system in Blantyre (a small percentage of sewer-connected customers), the data, though roughly estimated, can be considered as fairly reliable. The estimates for the amount of sludge treated and the treatment of sludge that is treated are likely the least reliable.

9. List of data sources

- Palamuleni, L. G. (2002). Effect of sanitation facilities, domestic solid waste disposal and hygiene practices on water quality in Malawi's urban poor areas: a case study of South Lunzu Township in the city of Blantyre. Physics and Chemistry of the Earth, Parts A/B/C, 27(11-22), 845-850.
- Republic of Malawi (2007). National Water Policy, Ministry of Irrigation and Water Development, Lilongwe, Malawi.
- UN-Habitat (2011). Malawi: Blantyre Urban Profile, Series: Urban Profiles. UN- Habitat, Nairobi, Kenya. ISBN: 9789211323771

SFD Blantyre, Malawi, 2018

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In collaboration with
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WASTE Advisers Malawi (WAM)
Blantyre City Council (BCC)

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Abbreviations

BCC	Blantyre City Council
BWB	Blantyre Water Board
CBD	Central Business District
HAS	Health Surveillance Assistant
JMP	Joint Monitoring Programme
LIA	Low Income Areas
MBS	Malawi Bureau of Standards
MDGs	Millennium Development Goals
MDU	Mobile Desludging Unit
MoEST	Ministry of Education Science and Technology
NGO	Non-Governmental Organization
NRW	Non Revenue Water
NSO	National Statistics Office
OD	Open Defecation
PEA	Pit Emptiers Association
RW	Revenue Water
SFD	Shit Flow Diagram
THA	Traditional Housing Areas
UNICEF	United Nations Children Fund
WASH	Water Sanitation and Hygiene
WFP-M	Water for People-Malawi
WHO	World Health Organization
WW	Wastewater
WWTP	Wastewater Treatment Plant
WWTW	Wastewater Treatment Works

1 City context

The city of Blantyre is the commercial and financial centre of Malawi and is located around 300 kilometres south-east of the capital, Lilongwe. Blantyre is situated at an altitude of approximately 1,050 meters above the sea level with a population of 1,068,681 (NSO, 2015) and covers 228km^2.The city is also the capital of the Southern Region as well as Blantyre District. The latter is divided into Blantyre Urban and Blantyre Rural; the district is further divided into traditional authorities (TAs).

The city of Blantyre itself is divided into 23 wards that each has a counselor at the Blantyre City Council, itself headed by the Mayor. Over 65 percent of the city's population live in unplanned, informal settlements (Table 1) characterized by high poverty rates, overcrowding, poor road access, and significant challenges related to access to social services, water supplies, and sanitation facilities (UN-Habitat, 2011). There are approximately 16 informal settlements in Blantyre. The informal settlements are Mbayani/Chemusa, Ntopwa, Ndirande. Nkolokoti/Makheta, BCA Hill, Nancholi, Chirimba, Naotcha, Kachere, Namiyango/Bangwe, Manyowe, Segerege/ Mulunguzzi, Misesa, Chigumula, Soche/Quarry and Kameza. However, due to the uncontrolled urbanization that is taking place in these areas, this number does not reflect the present situation as some settlements have expanded and/or taken on new names (CCODE, 2014). Informal settlements are growing due to rapid urbanization and the resulting shortage of decent, affordable housing in formal areas (UN-Habitat, 2011). The distribution of formal and informal settlement areas is shown in Figure 1.

Several hills ring the city and act as headwaters for rivers and streams which originate in, and radiate from the city, forming a natural drainage system with nine distinct catchment areas: Likhubula, Lunzu, Mombezi and Khombwi drain the northern part of the city, while Mudi, Chisombezi, Limbe, Luchenza and Mwampanzi drain the middle and southern parts. Due to the hilly topography of the area, the natural drainage channels are narrow and have steep sides and gradients (BCA, 1999). Most commercial activities within the city take place in two Central Business Districts (CBDs), located in Blantyre Central and Limbe Central (Figure 2). These areas have better public infrastructure (sewers, waste collection etc.) than most other areas of the city.

Table 1. Settlement types and coverage across Blantyre (Source: Blantyre City Council)

Settlement categories	***Comment***	***% Population***
Formal settlements	Planned and adequate land for service provision and access to plot	10
Traditional Housing Areas (THA)	Planned settlements. One house per plot	20
Informal settlements:	Unplanned settlement, dense, poor if no access to dwelling except on foot	70

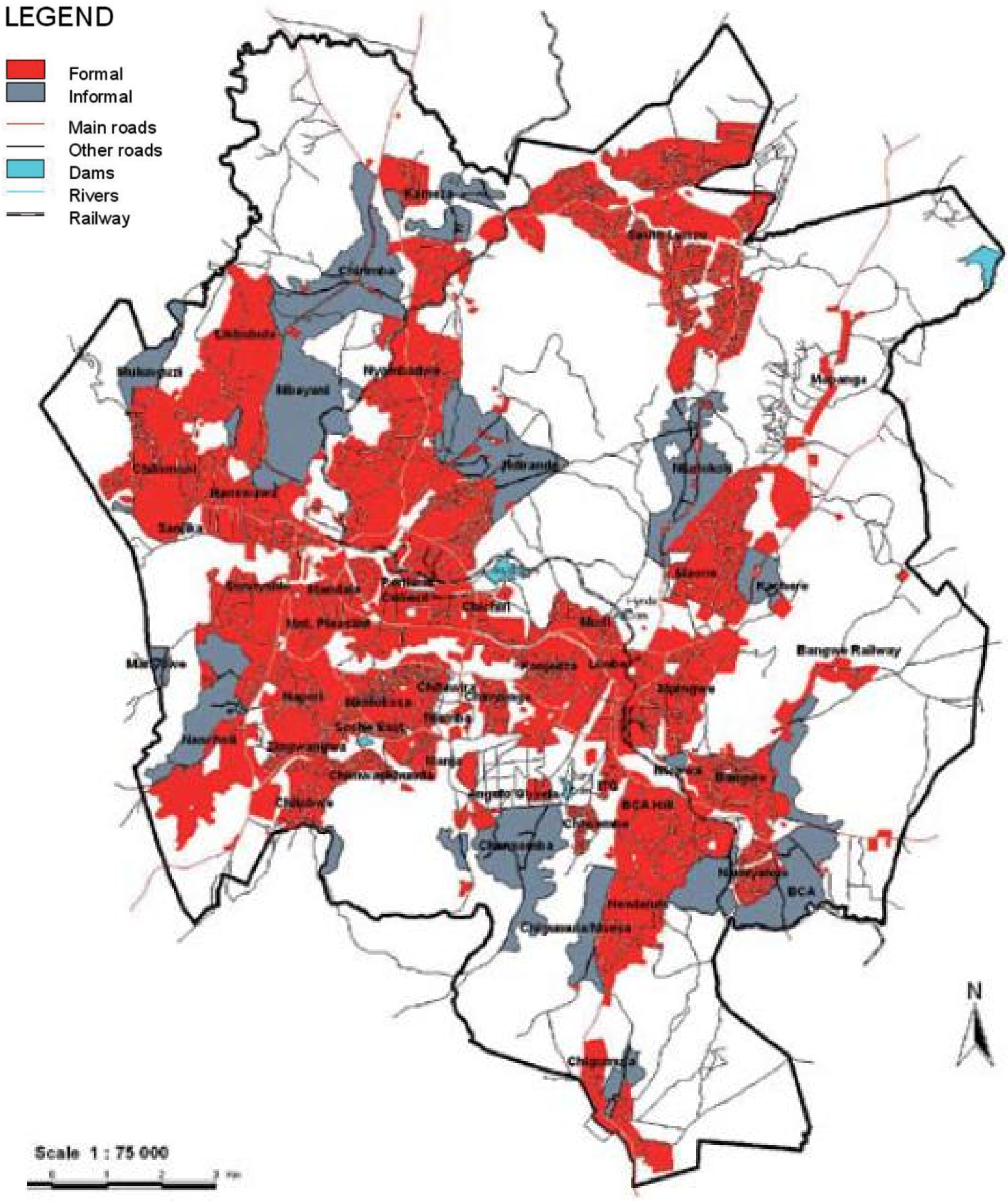

Figure 1. Formal and informal settlement areas of the city (UN-Habitat, 2011)

Figure 2. Blantyre City and Administrative boundaries (Source: Maolidi, 2012)

The city is divided by a tarmac and the main roads are paved paved, while the majority of roads are made of gravel and earth.

<u>Climate and elevation</u>

Blantyre has a sub-tropical climate. The rainy season is from November to April, with continuing light, cold showers (locally known as Chiperoni) from the end of May to July. The dry season is from May to October (Figure 3). The mean annual rainfall is 1,122 mm of which 80% falls during the rainy season. The city is generally cooler than the rest of the country, with mean monthly temperatures ranging from 19 °C during the cool season (May to July) to

26 °C during the hot season (September to November). The warm-wet season stretches from November to April, during which 95% of the annual precipitation takes place.

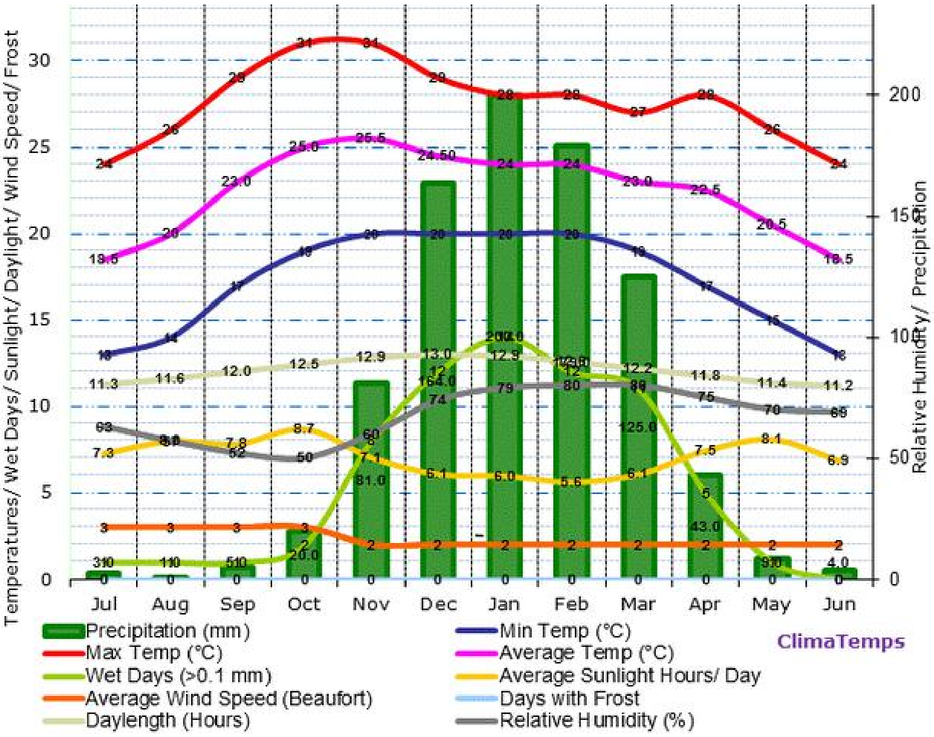

Figure 3. Climatic patterns of Blantyre (Source: ClimaTemps.com)

2 Service outcomes

This section shows the SFD selection grid (Figure 4). It also presents the available sanitation technologies in Blantyre. User interface, containment, emptying, transport and treatment technologies are presented.

List A: Where does the toilet discharge to? (i.e. what type of containment technology, if any?)	List B: What is the containment technology connected to? (i.e. where does the outlet or overflow discharge to, if anything?)									
	to centralised combined sewer	to centralised foul/separate sewer	to decentralised combined sewer	to decentralised foul/separate sewer	to soakpit	to open drain or storm sewer	to water body	to open ground	to 'don't know where'	no outlet or overflow
No onsite container. Toilet discharges directly to destination given in List B	T1A1C1				Significant risk of GW pollution Low risk of GW pollution					Not Applicable
Septic tank					Significant risk of GW pollution T1A2C5					
Fully lined tank (sealed)					Significant risk of GW pollution Low risk of GW pollution					
Lined tank with impermeable walls and open bottom	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution					Significant risk of GW pollution Low risk of GW pollution
Lined pit with semi-permeable walls and open bottom	Not Applicable									T2A5C10 T1A5C10
Unlined pit										T2A6C10 T1A6C10
Pit (all types), never emptied but abandoned when full and covered with soil										Significant risk of GW pollution Low risk of GW pollution
Pit (all types), never emptied, abandoned when full but NOT adequately covered with soil										
Toilet failed, damaged, collapsed or flooded										
Containment (septic tank or tank or pit latrine) failed, damaged, collapsed or flooded										
No toilet. Open defecation	Not Applicable								T1B11 C7 TO C9	Not Applicable

Figure 4. SFD selection grid for Blantyre

2.1 Containment

2.1.1 Pit latrines

Pit latrines are the most common sanitation technology in Blantyre, especially in poor/dense informal settlements. Most pits are self-dug shallow pits (2-3m) with a concrete or wooden slab. Pits are partially or fully lined with bricks, which should extend the life of the pit, though because of cost and habit, most pit owners abandon and cover old pits rather than empty them. Since there is no formal waste collection in poor housing areas, the main challenge of pit latrine emptying is the trash content that can be over 50%. In order to empty sludge then, an emptier must “fish” out the trash with a hooked rod, to prevent clogging equipment (manual or vacuum). Fishing requires extra time, and depending on the service provider, extra cost.

2.1.2 Improved latrines

The National Sanitation Policy and Vision 2020 program set the goal of 100% improved sanitation access in Malawi by 2020. NSP describes the features of an improved sanitation facility and lists some of the most common existing technologies: upgraded traditional latrines, V.I.P. latrines, ecological sanitation (*arborloo*, *fossa alterna*, *sky loo*, *children's loos*), pour flush, W.C, dome shaped slabs, sanitation platforms and integrated sanitation slabs. Despite the efforts of various NGOs, the proportion of improved latrines remains low, mostly due to acceptance, maintenance and cost (Chunga et al, 2016).

2.1.3 Flush toilets

Flush toilets are mostly found in high-income households, public administrations, offices and recreational centres (hotels, lodges, restaurants). In areas covered by the sewer network, flush toilets are directly connected without any on-site containment facilities. Buildings not connected to the network usually use a septic tank that is emptied once full.

2.1.4 Septic tanks

Septic tanks are found in both formal areas and in poorer housing areas where they are usually connected to a pour flush toilet.

2.2 Emptying technologies

Due to an increase in the demand for urban housing, townships are growing denser and less space is available for new pits. Thus, there is an increase demand for pit emptying in low-income areas that requires adapted technologies to deal with thick sludge, high trash content and narrow access road.

2.2.1 Manual Emptying

Manual emptying does not require any specific technology and is thus the cheapest and most basic emptying method. It is widely used in low-income areas where access and cost limits the feasibility of vacuum technology. Emptiers use buckets and shovels to transfer sludge from the pit to barrels (Figure 5).

Figure 5. A manual pit emptier (Source: Yesaya, 2016)

2.2.2 The Gulper

The Gulper is a hand pump that was designed for emptying pit latrines (Figures 6 and 7). The bottom of the main tube is first inserted into the sludge from the top of the pit. The worker then operates the hand pump that pulls the sludge from the pit up and through the spout into a barrel. This technology was developed and launched by WFP in 2012 as an alternative to manual emptying since it can be carried on foot in narrow informal housing areas. However, the Gulper is limited to a certain depth by the length of the main tube, and is not able to pump sludge that is either very thick or has a high trash content. Emptiers operating the Gulper usually charge 35,000 MWK/m^3 (USD 41/m^3) or pit emptying (WAM, 2016).

Figure 6. Pit emptier using a Gulper

Figure 7. A Gulper used for manual emptying (Source: Tilley, 2018)

2.2.3 Mobile Desludging Unit (MDU)

The MDU is a compact, heavy-duty mechanical pump that can pump up to 75 metres (Figure 8). In ideal conditions, it can fill and empty its 1m^3 tank in a few minutes and consumes about 0.2L of petrol per pit. The MDU is equipped with a fluidizing wand that sprays water in the sludge when it is too thick to be pumped. When the trash content exceeds 15% or sludge is too thick, the efficiency of the MDU is decreased because of hose clogging. In such cases, a “fishing” step is needed prior to the emptying, during which workers use hooked pole to remove the trash from the pit. There is currently one MDU operator active in Blantyre. Due to higher emptying fees most MDU customers are institutions and NGOs.

Figure 8. Mobile Desludging Unit (Source: Tilley, 2018)

2.2.4 Vacuum Trucks

Vacuum trucks still represent a small proportion of service providers in Malawi where manual emptying is most commonly used. Three privately owned and two public (operated by BCC) trucks provide emptying services in the city for a fee. The cost of mechanical emptying is cheaper than the MDU but still more expensive than manual services. Moreover, vacuum trucks are not suitable for narrow roads in dense, low-income areas and are very sensitive to FS that is either too thick or mixed with trash (1-3% trash content) Adding water prior to emptying can, in certain cases, solve the problem but vacuum trucks' flexibility remains very limited. Thus, vacuum trucks only service septic tanks in wealthy housing, administration and business areas.

2.2.5 Transport

In an effort to minimize the transport costs incurred by PEA members when hiring vehicle to dispose off emptied sludge at waste water treatment plant, Water for People-Malawi donated a second-hand 1 tonne truck to PEA. The fee-paying PEA members are allowed to hire the vehicle when conducting their pit emptying business at an affordable rate of 5,000 MWK (USD 7) (Figure 9). The vehicle is used for transporting workers, barrels and tools to the emptying site, and once the barrels are filled with sludge, bringing them to the disposal site. The fees for discharging at the treatment plant are fixed by BCC and were 4,000 MWK/m^3 (USD 5.5/m^3) in 2018.

A significant part of the FS that is emptied is never brought to the treatment plant. Manual emptiers often dig a pit in the vicinity of the facility they are emptying and bury the sludge instead of transporting it. Illegal disposal in nearby rivers is also common, both by manual emptiers and vacuum trucks. Because only one treatment plant accepts FS, the transportation from the emptying site to the treatment facility can represent a significant part of operating time and costs. Thus, operators choose not to bring the sludge to the treatment plant to avoid both disposal fees and extended travel time due to long distance and traffic jams (Yesaya et al, 2016).

Figure 9. Pit Emtpiers Association use a truck to transport barrels of sludge (Source: Yesaya, 2016)

2.2.6 Facilities connected to sewers

Areas connected to city sewers are shown in Figure 10. The areas connected are mostly high-income housing areas, businesses and industries. Blantyre has distinct sewer networks that are connected to a single treatment plant but remain independent from each other. This means that if the treatment plant of a given sewer network stops working, wastewater from this area cannot be transferred to another treatment plant and will remain untreated.

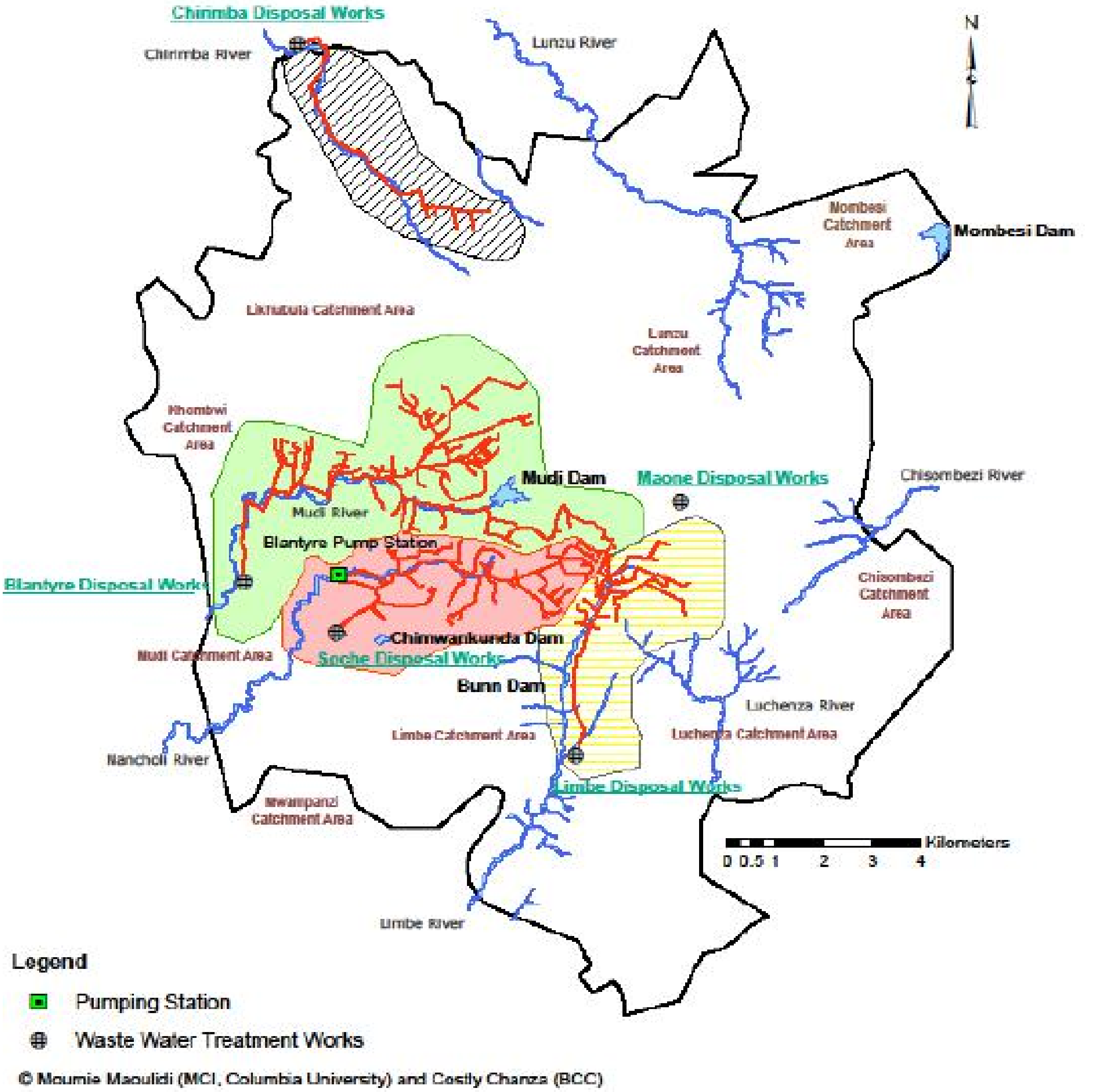

Figure 10. Sewer lines and treatment plants in Blantyre (Source: Maoulidi, 2012)

2.3 Treatment and discharge

BCC is responsible for the treatment of wastewater and is therefore in charge of the operation and maintenance of the treatment plants (Republic of Malawi, 2007). There are currently five treatment plants in Blantyre. None of the treatment plants are properly working and only Soche is semi-functional. A lack of maintenance and vandalism contribute to the current state. An absence of fencing ensures that the sites are used and looted by all who pass. Most information of this section directly come from a yet unpublished report from 2017 that asses the state of the Blantyre's treatment sites. This report was directed by WAM with the collaboration of BCC and compiled by Phekiso Consulting (Phekiso, 2017).

2.3.1 Blantyre Wastewater Treatment Plant

As shown in Figure 10, the works is located west of Blantyre in the Manase District and discharges into the Mudi River. The biggest of the treatment plants, it was originally built in the 1960s, but was expanded twice to increase the design flow to 8,600 m^3/day. The plant does not have any facility to handle FS and thus only wastewater is treated there.

The treatment works is not fully operational because of defective and/or missing equipment; most electrical and mechanical devices are either broken or lacking, preventing efficient treatment. “Currently, raw sewage virtually bypasses the crucial treatment units' processes and operations, fed directly into lagoons prior discharge into Mudi Stream. Little or almost no treatment occurs.” (Phekiso, 2017).

It was shown with a numerical modelling of the WWTP that even with the sewage passing through all designed treatments, the legal threshold value would not be achieved. Nevertheless, the expected COD removal would still be about 70% with properly refurbished infrastructure.

2.3.2 Soche (Zingwangwa) Wastewater Treatment Plant

The treatment plant is located south-west from the city centre as shown in Figure 10 and it uses a tributary of the Naperi River for effluent discharge (Figure 11). The plant is accessible by a tarred road and is the only plant that has a facility for FS collection and treatment. It is the oldest treatment plant of the country: it was built in the 50s and extended in the 70s to the current design flow of 4,100 m^3/d. The Sanitation Master Plan Report from 1995 reported an influent flow of 6,440 m^3/d.

Soche WWTP is second in terms of design treatment capacity, but it also needs repair and/or replacement of mechanical and electrical equipment. Recent testing done by WAM showed that the treatment plant achieved an average of 80% COD reduction with residual COD around 150mg/L in the effluent. Numerical calculation estimated a residual COD around 70 mg/L with refurbishment.

There were faecal sludge drying beds, but there is no access road and the beds are not maintained (Figure 12) and the FS is therefore co-treated with wastewater. As such, the quantity of FS added should not exceed 2.5% of the total volume. Assuming this quantity (no more) and perfect operation conditions, the residual COD was calculated to be around

100mg/L. Given the number of households that rely on pits that require emptying, more and better faecal sludge treatment options are required to prevent overloading this works.

FS discharging is managed by the staff of the plant that charge a fee to the emptiers. The fee is fixed and does not depend on the quantity. The only difference that is made is between manual emptiers that discharge drums and vacuum trucks. Once the entry fee is paid, users can then discharge as much FS as they want. Emptiers often arrive at the plant after workers leave. This is mainly because pit emptying can be very time consuming but also due to early closing hours of the treatment plant. In these cases, emptiers make an agreement with security guards to be allowed inside to discharge.

Figure 11. Effluent from Soche WWTP is discharged into the Naperi River (Source: Yesaya, 2016).

Figure 12. Drying beds at Soche WWTP (Source: Yesaya, 2016)

2.3.3 Limbe Waste Stabilization ponds

The Limbe plant is located south of the city as shown in Figure 10 and was built in the 70s to treat domestic sewage with a further extension in the 80s. It consists in a set of 16 stabilization ponds forming 4 parallel treatment systems that discharge their effluent into Limbe stream. The treatment was designed to accept only wastewater from sewers and thus is not able to properly treat FS from septic tanks or pit latrines.

The trunk sewer that is supposed to bring the sewage to the plant has been partially vandalized and no longer forms a continuous pipeline. This means that only sewage brought by tankers can be treated there, even though the plant is not supposed to accept any septic tank sewerage. The rest of the infrastructure has been vandalized and is poorly maintained; every electrical and mechanical device is broken or missing. The first pond is currently used for FS and solid waste; this practice has led to a pond full of sludge without any effluent flowing to the following ponds. Due to a lack of security, the ponds are also used for the dumping of chemical waste by local businesses. Thus, most other ponds are unused and overgrown with grass. This treatment plant is currently more a discharging site than an actual treatment facility.

2.3.4 Chirimba Wastewater Treatment Plant

The Chirimba plant is located near the airport, north-west from the city as shown in Figure 10. This plant is relatively new but has never been in use and is in a poor state due to a lack of maintenance and vandalism. The plant would be an opportunity for nearby industries and households, although it needs to be refurbished to decent working conditions. The design of the plant does not make it suitable for co-treatment of FS.

2.3.5 Maone Wastewater Treatment Plant

The Maone WWTP is a small facility that was built in the 60s in the eastern part of Blantyre (Figure 10). The plant was built by a private company to serve the Maone residential area. The site is totally abandoned and “nothing of the original works can be of any use”.

2.4 SFD Matrix

The values used to create the SFD are discussed in the following sections. Of the values required, only open defecation (JMP 2017) and connection to sewer (Maoulidi 2012) were clearly mentioned in literature. The other values were mostly estimated during meetings with Blantyre City Council, Waste Advisers Malawi, and Water for People over the course of 2 years (Figure 13).

Blantyre, Blantyre, Malawi, 17 Oct 2017. SFD Level: 1 - Initial SFD
Population: 1068681
Proportion of tanks: septic tanks: 100%, fully lined tanks: 100%, lined, open bottom tanks: 100%

System label	Pop	W4a	W5a	F3	F4	F5
System description	Proportion of population using this type of system	Proportion of wastewater in sewer system, which is delivered to centralised treatment plants	Proportion of wastewater delivered to centralised treatment plants, which is treated	Proportion of this type of system from which faecal sludge is emptied	Proportion of faecal sludge emptied, which is delivered to treatment plants	Proportion of faecal sludge delivered to treatment plants, which is treated
T1A1C1 Toilet discharges directly to a centralised combined sewer	10.0	20.0	70.0			
T1A2C5 Septic tank connected to soak pit	25.0			50.0	85.0	50.0
T1A5C10 Lined pit with semi-permeable walls and open bottom, no outlet or overflow	11.0			90.0	15.0	50.0
T1A6C10 Unlined pit, no outlet or overflow	21.0			50.0	15.0	50.0
T1B11 C7 TO C9 Open defecation	2.0					
T2A5C10 Lined pit with semi-permeable walls and open bottom, no outlet or overflow, where there is a 'significant risk' of groundwater pollution	11.0			90.0	15.0	50.0
T2A6C10 Unlined pit, no outlet or overflow, where there is a 'significant risk' of groundwater pollution	20.0			50.0	15.0	50.0

Figure 13. SFD matrix for Blantyre

2.4.1 Ground water pollution assumptions

Although little information about the hydrogeology of Blantyre was found in the literature, observations and expert information agreed that most housing areas have a groundwater table at a depth around 10 m. However not all areas have such deep water tables and may be more vulnerable to faecal contamination from pit latrines (Palamuleni, 2002). Cracks in bedrock may facilitate the transport of pit latrine effluent; heavy rains increase the possibility of groundwater contamination even more. Furthermore, households take advantage of the rainy season to avoid formal emptying by allowing the pit to overflow through a strategic opening (Maoulidi, 2012). Due to the variations of groundwater depth and variations in rainfall, 50% of the pit latrines were considered to safely contain sludge while the other half represents a risk for groundwater. in the final diagram, 50% of all unemptied latrines are unsafely managed since it was assumed they are located in areas with a risk of groundwater pollution. The other 50% of the latrines that are not emptied are considered safely managed because the sludge is assumed to be contained in ground where it does not pollute the nearby water.

Septic tanks were considered as safe containment; the assumption was made (based on local knowledge and experience) that septic tanks are a) well built from thick concrete, b) fairly shallow, and c) located on larger properties (i.e. richer people), with a safe distance away from other households or water sources. Unlike in Asia, where septic tanks are common due to the abundance of water, residents of Blantyre are limited by constant water shortages and so few would choose or construct the technology unless they were able to pay for and store a constant supply of increasingly rare water.

2.4.2 Sanitation technologies

The proportion of each sanitation facility's usage within Blantyre is challenging to accurately estimate, mostly due to the uncontrolled urban development of some low-income townships. Various surveys have addressed specific areas but no recent summary for the whole city exists. Based on the available literature (Maoulidi, 2012; Chunga et al, 2016; Palamuleni, 2002) and meetings with different stakeholders of the WASH sector in Blantyre (Water for People, WAM, BCC), the distribution of sanitation technologies in Blantyre was estimated and is summarized in Table 2. The proportion of users connected to the sewer was estimated to be 10%, while estimating 25% for septic tanks. Most households still rely on pit latrines, with 22% of all users using lined pits and 41% using unlined pits. The percentage of open defecation (OD) is assumed to be 2%, based on the most recent value for urban areas in Malawi from the WHO/Unicef Joint Monitoring Report (2017). This value is likely an underestimate, given the rate of population growth compared to the availability of sanitation infrastructure.

Table 2. SFD matrix input values

Technology	User [%]	Emptying [%]	TP Delivery [%]	Treatment [%]
Connection to sewer	10	-	20	70
Septic tank	25	50	85	50
Lined pit latrines	22	90	15	50
Unlined pit latrines	41	50	15	50
Open defecation	2	-	-	-

2.4.3 Emptying rate

The emptying rate was estimated based on observations and was agreed on with stakeholders from the WASH sector. Faecal sludge contained in pits that is not emptied is usually left in the ground because households prefer to cover the existing pit and dig a new one to avoid emptying fees. This is mostly the case with unlined pits since lined pits are more expensive to build and households are more likely to pay for emptying than building a new latrine. Emptying rates of 50% for unlined pits and 90% for lined ones were used (Table 2). The decrease in the quantity that is emptied compared to what is produced can also be that a fraction of the FS leaks in the ground, leading to lower quantities to empty. Septic tanks are less likely to leak and very few households would leave it once full. Most of the FS that is never emptied is more likely to have been deteriorated by anaerobic digestion in the septic tank. As septic tanks are common in middle- to high-income housings, businesses and administrations, users are more likely to be able to afford the emptying fees.

2.4.4 Treatment plant delivery rate

Literature (Maoulidi, 2012; Chunga et al, 2016) and observations show that not all emptied FS end up in a treatment plant. Some emptiers dump illegal in nearby rivers or fields to avoid transportation costs and discharging fees at the treatment plant. The delivery rate was estimated based on a survey that was led at Zingwangwa treatment plant to assess the quantity of FS that is dumped by emptiers compared to the population that rely on on-site sanitation facilities. This survey showed that mostly vacuum trucks come to the plant for dumping while only few manual emptiers do, even if most pits are manually emptied. Based on this survey a delivery rate of 15% for both lined and unlined pits was assumed in Table 2, even though this number was calculated using very conservative assumptions; the actual rate might be much lower, especially in areas that are uneasy to access or far from Zingwangwa treatment plant. Because septic tanks are usually emptied by vacuum trucks that can empty several septic tanks before discharging at the TP, a delivery rate of 85% was assumed in Table 2. Again, this might be overestimated since vacuum truck operators tend to illegally dump the content of their tank to avoid transportation and discharging costs as well as time loss due to traffic jam, especially when they would have to cross from one side of the city to another. The issue of delivery also arises with households connected to the sewers. Because four of the 5 (80%) of the sewer networks are not connected to functioning treatment plants, we assumed that only 20% of sewage was delivered to treatment (i.e. 20% TP Delivery in Table 2), Leakages in the sewer lines also lead to wastewater not being treated, but these were not incorporated into the calculation; the estimate is therefore quite conservative.

2.4.5 Treatment rate

The treatment rate was estimated in terms of COD reduction between influent and effluent. Because of undersized and poorly maintained treatment facilities, effluent often exceeds discharge limits leading to an average treatment rate much lower to what was initially designed during the TP's conception. Furthermore, the treatment rate also depends on the amount of water coming to the TP. Due to missing valves between the various pieces of equipment, it is not possible to control the flow from one pond to another. This means that when the influent rises, especially during the rainy season, the wastewater freely flows from pond to pond and ends up being discharged into the river with almost no treatment. Despite this observation, a treatment rate of 70% was assumed following a short measurement campaign by WASTE Advisers Malawi at the Zingwangwa WWTP (Table 3) and showed an average treatment rate of 80%. Because this TP is the one showing the best working conditions and because these values do not take seasonal variation into account, the value in Table 3 was reduced to 70%, even though it remains a very optimistic year average for all TP in the city. Numerical modelling was also available but was assuming perfect working conditions and thus a too strong assumption to accept the modelled values (Phekiso, 2017). COD values for influent and effluent at the Blantyre WWTP are shown in Table 3. Note however, that it is not known if, or how much faecal sludge was processed during the sampling. Currently, the BCC does not conduct regular (daily or weekly) sampling and so these are the most recent data that were available. Because FS has higher levels of BOD and COD and therefore requires more treatment than wastewater, the treatment rate was approximated to be a lower than for wastewater, and thus decreased to 50% in Table 2.

Table 3. COD reduction at Blantyre WWTP (Source: WASTE Advisors Malawi, 2017)

	COD [g O_2/l]	
Date	**Influent**	**Effluent**
17.08.17	0.61	0.17
24.08.17	0.74	0.13
13.09.17	0.86	0.13
Average	0.74	0.14
Efficiency	80.54%	

The treatment efficiency was estimated based in the COD removal efficiency, in this case around 80%. According to the Malawi Bureau of Standards (MBS) (section 3.1.1 Policy), the COD tolerance limit values for effluent from WWTPs discharging into the environment is set to 30 mg/L. Values shown in this Table 3 are 0.14-0.17 g O_2/L or 130-170 mg/l, clearly exceeding the limit of 30 mg/l. Thus, according to this standard, the WWTP, though achieving a significant reduction, is not treating the wastewater to an acceptable (national) limit.

However, given the fact that there is so little sewer-transported wastewater in the city, and because so little of it reaches the treatment plant (only about 20%), the treatment level, and ultimate quality of the effluent discharged, has little impact on the overall SFD. It is still important to note that although the reduction is important, it is not sufficient or legal.

2.5 SFD Graphic

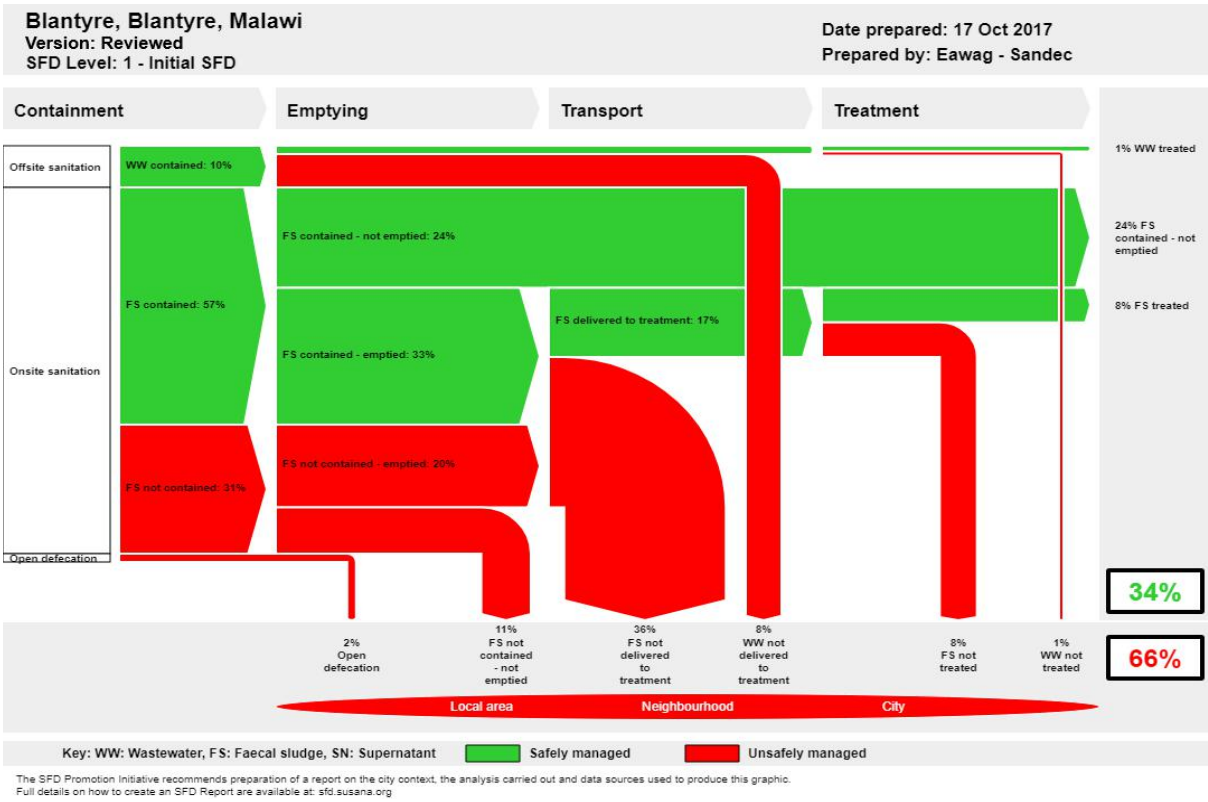

Figure 14. SFD of Blantyre

The SFD graphic shows that 66% of the excreta is unsafely managed and 34% is safely managed (Figure 14). The 34% of the excreta safely managed originates from wastewater (1%) and FS (8%) treated at the WWTPs and sludge contained and not emptied in areas of low risk of ground water pollution (24%).

The 66% of excreta not properly managed consists of: 8% of wastewater not delivered to treatment; 1% of wastewater delivered to treatment but not treated; 8% of FS delivered to treatment but not treated; 36% of FS emptied from onsite systems but not delivered to treatment; 11% of FS not contained from pits located in areas of high risk of groundwater pollution and 2% of people practising open defecation.

Eliminating open dumping of pit sludge would have a significant impact on the quantity of sludge that is unsafely managed (36%) and should be the first priority for the BCC to address.

Following that, the siting and containment of on-site sanitation should be addressed. The percentage of sludge that could cause groundwater pollution is both spatially and temporally difficult to estimate: latrines that are in low-lying areas may never flood, while latrines that are tens of metres above the groundwater table may be situated on cracks or sensitive springs. The age and quality of the pit latrine construction, as well as the interactions with the increasingly erratic weather patterns and city-use patterns, mean that the actual quantity of safely managed sludge in pit latrines could vary significantly from the values shown. That said, ensuring that pits are designed to suit the location (lined when necessary), located appropriately (away from rivers and boreholes), will help to reduce the amount of unsafely managed sludge in the city. Proper stormwater management that ensures normal and flood waters are directly safely away from houses, will reduce the chance of pit flooding, infiltration, and eventually groundwater contamination.

Despite the fact that the old, leaky sewers are a constant, city-wide source of contamination and of discussion, improving the sewer system would have a small overall impact, but would be extremely difficult and expensive, if not impossible to do.

2.6 Levels of uncertainty

The biggest challenge of this report was access to reliable information. The lack of surveys focused on the presence of infrastructure and reliable treatment measurements, led to significant uncertainties and most values were estimated based on proxy information and stakeholders' expert knowledge. The fast and uncontrolled urbanization as well as population growth in Blantyre means that information dates quickly and is unreliable. There is indeed a need for deeper focused investigations on that matter, including assessment of population's habits, stakeholder's activities and measurements of FS, WW and effluent samples.

3 Service delivery context description

3.1 Policy, legislation and regulation

3.1.1 Policy

The Democratic Republic of Malawi includes the protection of public health in its constitution. Written in 1994 with further amendments through 1999, Section 13(d) states that the government "shall provide adequate health care commensurate with the health needs of Malawian society and international standards of health care" (Republic of Malawi, 1994). Since then, several documents were published to safeguard public health. These are described in the following sections.

Water Resources Act No.2
The Act was established in 1995 and gives the Blantyre Water Board (BWB) the mandate to extend its water coverage areas, pending ministerial approval. The Act empowers the BWB to make, construct and maintain all such works that are necessary and convenient for creating, maintaining and extending waterworks to supply water for domestic, public and business purposes. The act gives the BWB the power to maintain gutters and sewers, and for all other purposes to which water and water works are supplied or applicable. Lastly, the act gives power to BWB to levy and revise its water charges (Republic of Malawi, 1995)

National Water Policy (NWP)
The National Water Policy was published in 2005 as a revision of the previous policy from 2000. It is meant to overcome the challenges of the water sector in Malawi by governing the management, development and service delivery of all aspects linked to water. The goal is to guarantee the sustainable and safe use of water resources as well as increasing access to safe water for consumption. The NWP describes recommended usage limits for different sectors and contains a set of general rules for public governments to implement. It also clarifies the role of each public stakeholder in terms of environment protection, service management and equitable access to water resources (Republic of Malawi, 2005).

Environment Management Act
The Environment Management Act of 1996 makes provision for the protection and management of the environment and the conservation and sustainable utilization of natural resources. It stresses that it is the duty of every person to take all necessary and appropriate measures to protect and manage the environment, to conserve natural resources and to promote sustainable use of natural resources in accordance with the Act. Section 5(1) of the Act ensures that every citizen has a right to a clean and healthy environment. Through its enforcement, the policy strives to protect public health and the sustainability of resources (Republic of Malawi, 1996).

National Sanitation Policy
The National Sanitation Policy, published in 2008, was developed by an inter-departmental group. It was based on several surveys assessing sanitation conditions in both urban and rural areas. It advocates for hygienic behaviours to limit the spread of faecal-oral diseases,

discourages open defecation (OD) and encourages people to construct and use improved sanitation facilities. The policy further fixes a set of objectives that must be fulfilled by the year 2020 in order to achieve access to improved sanitation, safe hygiene and sustainable environmental management for all of Malawi. The social and economic gains of such improvements are also highlighted. Guidelines are set for wastewater treatment, sanitation and solid waste management, with sustainable environmental management as the main goal. The objectives are divided by scale: national, rural areas, cities, schools, prisons, hospital. Also included is guidance on the needed investments in term of staff and infrastructure at each level (Republic of Malawi, 2008).

<u>National Decentralization Policy</u>
The National Decentralization Policy (NDP) of 1998 is a general set of rules concerning the division of powers into districts. It states which matters are to be treated at a local, regional or country level and by which administrations. It states that environmental sanitation as well as the provision of water supply including boreholes, piped water, protected wells and distribution fall are the be managed by District Assemblies (Republic of Malawi, 1998).

<u>Malawi Bureau of Standards (MBS)</u>
MBS is responsible for setting all standards and specifications in Malawi. The most relevant ones for the WASH sector are as follows:

- MS 214:2005 defines the limit values for dissolved material in drinking water as well as standard testing methods.
- MS 733:2005 defines the standards for a borehole to be used a safe water source. This includes the limit values for contaminants in the well, hygiene and handling practices and standard methods for water testing.
- MS 691:2015 defines the limit values for effluent discharges into the environment. For effluent emanating from treatment plants the limits are:
    - BOD tolerance limit: 20 mg/L
    - COD tolerance limit: 30 mg/L
    - TSS tolerance limit: 30 mg/L

To date, there is no policy specifically dedicated to faecal sludge management nor is it specifically mentioned in any of the relevant policies.

3.1.2 Institutional roles

A diverse range of stakeholders play roles in sanitation in the city of Blantyre; their respective roles are discussed below.

<u>Ministry of Health</u>
At the national level, the Ministry of Health (MoH) is responsible for health in Malawi. It is mandated to oversee all public hospitals in the country and sets guidelines for appropriate health service delivery in private hospitals. The Ministry of Health has Health Surveillance Assistants (HSA) that act as health advisors and they are the point of contact for health issues in their respective location.

Ministry of Agriculture, Irrigation and Water Development

The Ministry of Agriculture, Irrigation and Water Development is responsible for water supply and sanitation services through the Department of Irrigation and Water Development (DIWD). Its mandate is to ensure the sustainable management of water resources to meet domestic, agricultural and industrial demand as well as developing access to improved sanitation facilities and safe hygiene practices. The DIWD is further divided in four sectors:

1. Water Resources Management and Development.
2. Water Supply Services.
3. Irrigation Services.
4. Sanitation and Hygiene.

The mandate of each of these sectors is summarized in Figure 15.

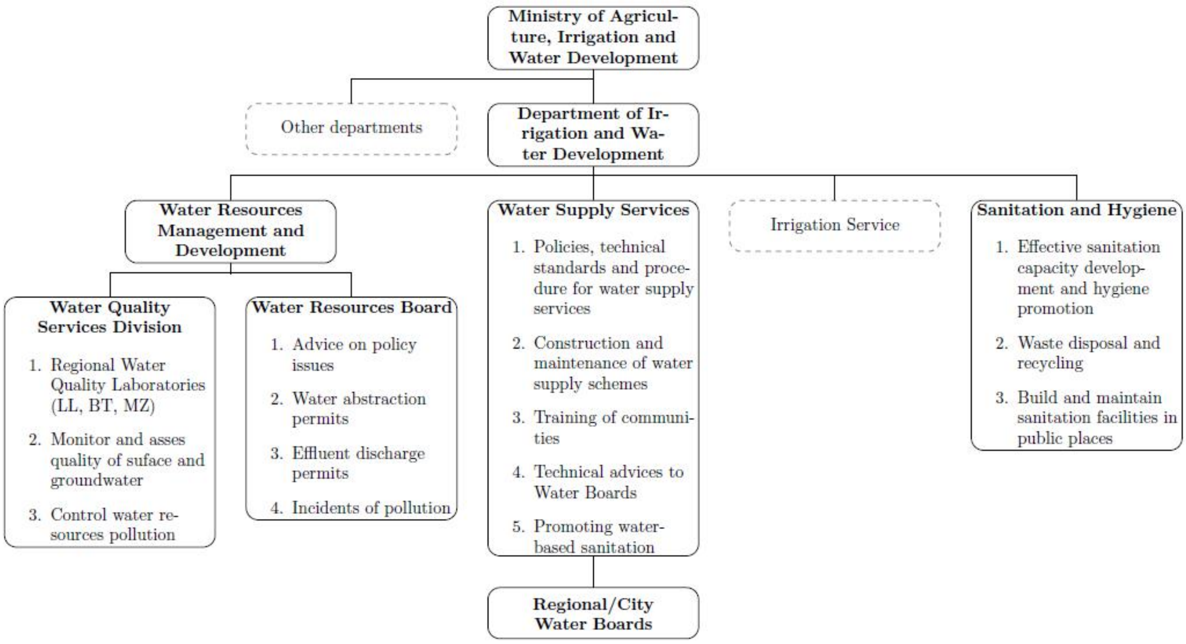

Figure 15. Tasks and bodies under the Ministry of Agriculture, Irrigation and Water Development (Source: S. Collet)

Blantyre Water Board

The Blantyre Water Board (BWB) is responsible for the piped, potable water supply in Blantyre and surrounding areas, for commercial, industrial, institutional and domestic use. The water is pumped from the Shire River at Walkers Ferry, about 50 kilometres away from the city. BWB is responsible for the raw water extraction and treatment, operation and maintenance of the distribution network, and the billing of water services to users connected to the network.

Malawi Bureau of Standards

The Malawi Bureau of Standards (MBS) is the statutory organization that promotes metrology, standardization and quality assurance. It publishes Malawian Standards (MS) that state tolerance limits for water qualities and effluents discharge.

Blantyre City Council

The Blantyre City Council (BCC) is the governing assembly of the city with councilors representing each ward. The Council is mandated by the Local Government Act and the National Sanitation Policy to manage the city's wastewater. The BCC operates five wastewater treatment plants in Blantyre namely: Soche (Zingwangwa), Blantyre, Chilimba, Maone and Limbe (Figure 4). Operations are supported by city rates (property tax) and by fees levied on faecal sludge dumping at the wastewater plants.

Solid waste collection and disposal is also operated by Blantyre City Council. It owns collection trucks that operate in the formal areas on a daily or weekly basis, although the collection frequency varies depending on the location and time of year (UN-HABITAT 2011, Palamuleni 2002). There is no solid waste collection in the informal settlements.

BCC is also responsible for the urban development of the city through the Directorate of Town Planning (DTP). Activities include the approval of new buildings and the planning of infrastructure.

Pit Emptiers Association

The Pit Emptiers Association (PEA) is a formal network of sanitation entrepreneurs who provide sanitation solution to households and institutions. Services include the emptying of in-situ sanitation facilities, building of improved toilets based on Water for People's catalogue and the sale of toilet-related products. The association had 15 paid and 43 regular members registered in 2016 (Water for People, 2016). Paid members are allowed to hire pick-up trucks (to carry faecal sludge) at a subsided price. The PEA was formed through a joint effort by Water for People and local entrepreneurs to enhance the recognition of this service as a key factor in a successful sanitation plan.

WASTE Advisers Malawi (WAM)

WASTE is a non-governmental organization providing expertise in sustainable solutions for sanitation and solid waste management. Their work emphasizes the concept of sustainable service chains and they do so by bringing stakeholders together to build efficient solutions. Focusing on faecal sludge management, they were instrumental in the design and testing of the Mobile Desludging Unit (MDU) for pit emptying.

Water for People

Water for People is an international NGO, which exists to develop high quality drinking water and sanitation services that can be accessed by all. Water for People envision a world where every person has access to reliable and safe drinking water and sanitation.

They promote sanitation through a market-oriented and business-based strategy called Sanitation As A Business (SAAB). This involves the establishment of sanitation businesses that are driven by both small scale and medium scale entrepreneurs. Businesses range from latrine construction/upgrading to pit emptying businesses targeting households and institutions that demand for it.

Currently, Water for People has plans to build a FS transfer station and Decentralized Faecal Sludge Treatment Plants (DEFAST) which will help to reduce the operational costs for the entrepreneurs operating pit emptying business and also deter emptiers who dump sludge into convenient water bodies and those who bury the FS into a dug pit as they avoid the costs of transferring the sludge to a distant wastewater treatment plant (Yesaya et al, 2016).

Pump Aid

Pump Aid (PA) is an NGO active in the WASH sector in Malawi, mostly in poor rural areas. PA is mostly funded by the UK Department for International Development and UNICEF. Its main objective is improving the access to improved sanitation facilities and to safe drinking water. The projects led by Pump Aid emphasize the involvement of local communities in the process. Sanitation projects are based on Community-led Total Sanitation (CLTS). Pump Aid improves access to clean water sources with a sustainable water pump program. Their water pumps are built where there is no water source, or where unprotected wells may lead to water contamination. Pump Aid supports the self-supply approach against water poverty, which is based on the training of community members in the building and maintenance of simple technologies as well as business and marketing skills. The entrepreneurs are then able to run a sustainable business that improves the WASH sector in their own communities without external funding.

Center for Water, Sanitation, Health & Appropriate Technology Development

The Centre for Water, Sanitation, Health and Technology Development (WASHTED) was established in 2003 at the Malawi Polytechnic: a constituent college of the University of Malawi (UNIMA). WASHTED is a semi-autonomous training and research centre within the Faculties of Engineering and Applied Sciences, offering a multi and interdisciplinary range of skills through its affiliated members. The main objectives of the centre include capacity building in the field of water, sanitation and appropriate technology development; conducting research and consultancy; developing and adopting technologies appropriate to the local environment; and disseminating information to national and international stakeholders.

2.1.3 Service provision

The National Sanitation Policy (NSP) provides the overall objectives of the WASH sector in Malawi and is meant to be the main driving policy to achieve them: "[…] it is to provide both guidelines and an action plan whereby 2020 all the people of Malawi will have access to improved sanitation, safe hygienic behavior will be the norm and recycling of solid and liquid waste will be widely practiced […]". NSP and other policies also emphasize the leading role of public administration in managing water and sanitation related services.

BCC is operating and maintaining the sewer networks and treatment plants though has no dedicated facility for faecal sludge treatment. BCC also operates some public toilets in the formal areas of the city. The Pit Emptiers Association provides emptying services for a fee either using manual or motorized devices. Vacuum trucks are mostly used in formal wealthy settlement areas were septic tanks are common, while manual devices are widely used in dense informal areas. Partnerships between NGOs and research teams have made small contributions to the number and functionality of various WASH technologies in Blantyre.

3.1.3 Service standards

The Malawi Bureau of Standards (MBS) has defined a set of directives called Malawi Standard (MS). MS documents define the tolerance for each contaminant in wells, drinking water and treatment plant effluents as well as standardized measurement methods.

The National Sanitation Policy (NSP) provides a definition of an improved pit latrine:

1. allow for the safe disposal of faeces into either a cesspit, septic tank or working sewer.
2. offer privacy for the user.
3. be safe for the user to use, for example not in a dangerous state, liable to imminent collapse or dangerously unhygienic.
4. be functional, i.e. the cesspit or septic tank should not be full or overflowing.
5. must have a continuous source of water.

In the case of waterborne sewerage, the whole system should be functional including the treatment plant, otherwise a waterborne waste water system is merely shifting the problem elsewhere, where it may be polluting rivers or streams used by residents for other purposes such as washing clothes or bathing.

Unfortunately, MBS does not have the mandate to monitor or enforce their standards and the adherence to these codes is largely left to individuals to follow.

3.2 Planning

3.2.1 Service targets

The National Sanitation Policy has a target where by 2020 all people in Malawi will have access to improved sanitation, safe hygienic behaviour will be the norm, and recycling of solid and liquid waste will be widely practised leading to a better life for all the people of Malawi, through healthier living conditions, a better environment and a new way for sustainable wealth creation (NSP, 2006). The policy mainly addresses the need for improving the access to both basic and improved pit latrines in towns and cities. However, there are no clear goals related to FS emptying, transport, or disposal. The policy provides guidelines and an action plan in the form of a National Hygiene and Sanitation Programme (NHSP); the guidelines forms the basis of a Sector Wide Approach (SWAP) for sanitation.

3.3 Reducing inequity

3.3.1 Current choice of services for the urban poor

About 65% of the population that uses pit latrines, use unlined pit latrines. As there is a limited number of treatment plants that accept FS, emptying costs can vary significantly depending on the location but the current price is approximately USD 7 per 200L drum of sludge that is removed; a cubic meter of sludge is therefore about USD 35 though the price will depend on the difficult of the work, road access, the need for trash removal and the distance to the dumping facility (driving to which may consume a considerable amount of time and fuel).

3.3.2 Plans and measures to reduce inequity

Water for People and the Blantyre City Council have plans to construct transfer stations which will reduce the travel time required of emptiers wishing to dispose of their sludge in a hygienic manner.

4 Acknowledgements

We wish to thank all participants at WfP, WAM, and BCC who generously donated their time and knowledge to this endeavour.

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6 Appendix

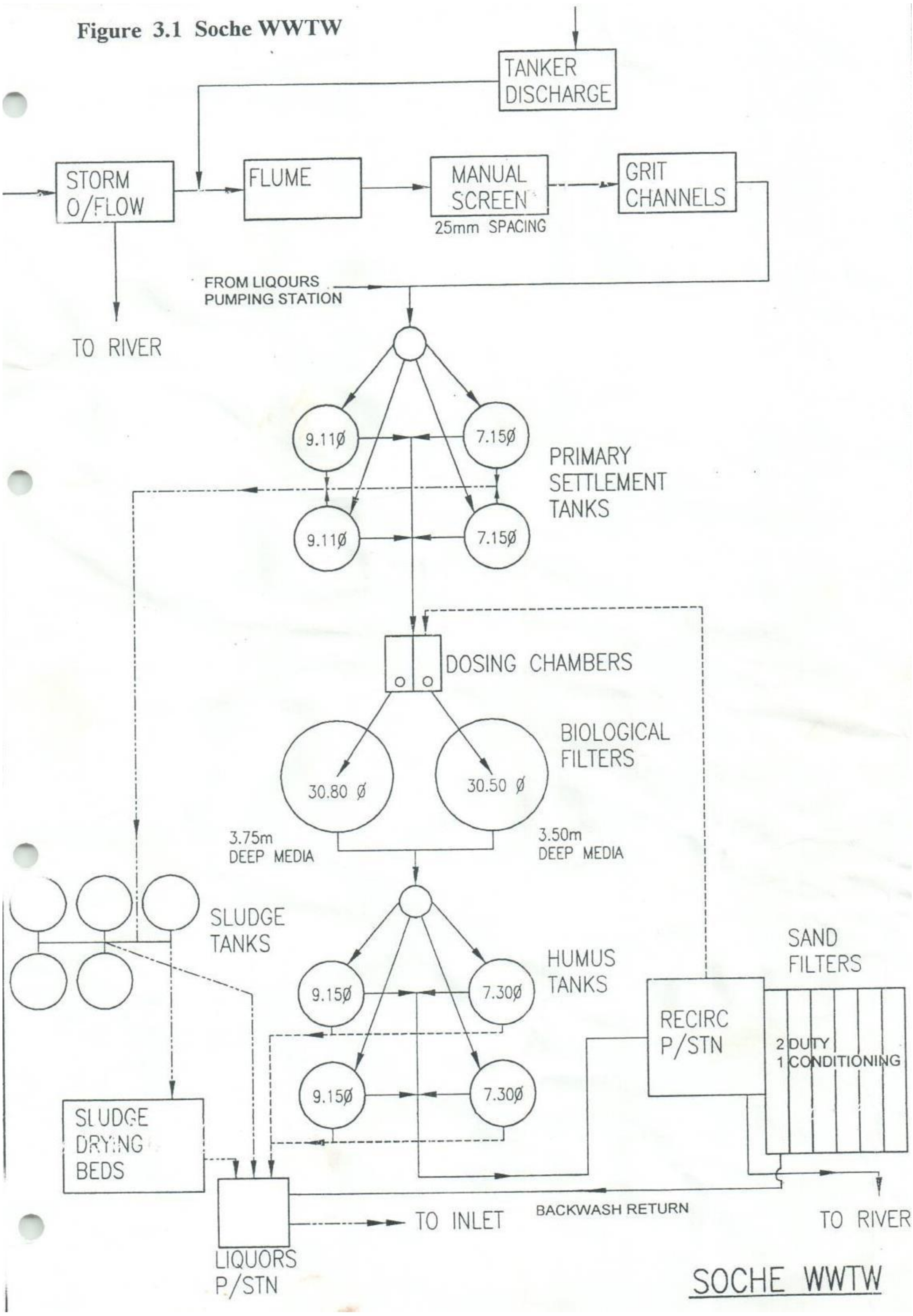
Figure 3.1 Soche WWTW
TANKER DISCHARGE
STORM O/FLOW
FLUME
MANUAL SCREEN
25mm SPACING
GRIT CHANNELS
FROM LIQOURS PUMPING STATION
TO RIVER
9.11Ø
7.15Ø
PRIMARY SETTLEMENT TANKS
9.11Ø
7.15Ø
DOSING CHAMBERS
BIOLOGICAL FILTERS
30.80 Ø
30.50 Ø
3.75m DEEP MEDIA
3.50m DEEP MEDIA
SLUDGE TANKS
HUMUS TANKS
9.15Ø
7.30Ø
9.15Ø
7.30Ø
SAND FILTERS
RECIRC P/STN
2 DUTY
1 CONDITIONING
SLUDGE DRYING BEDS
TO INLET
BACKWASH RETURN
TO RIVER
LIQUORS P/STN
SOCHE WWTW