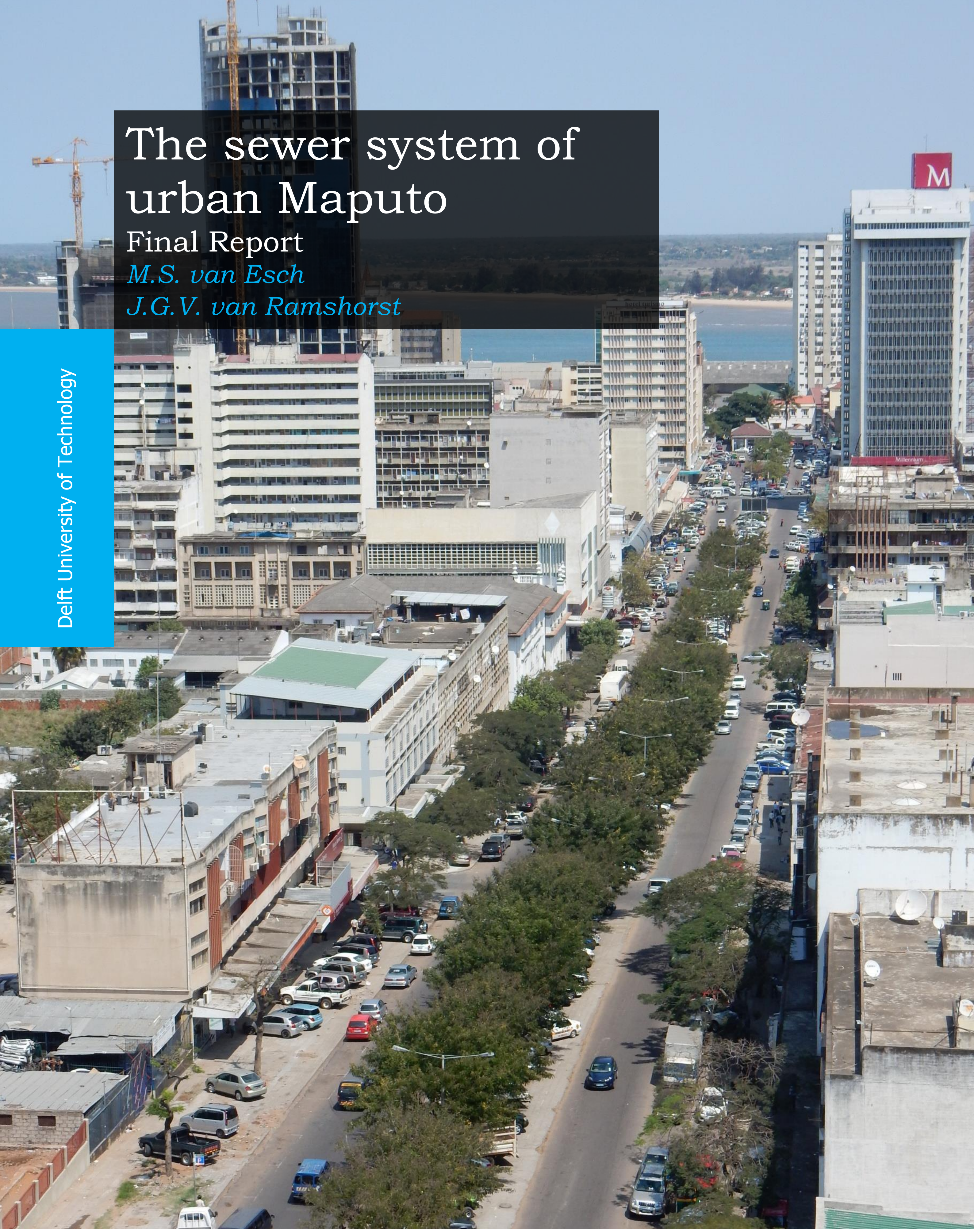
The sewer system of urban Maputo

Final Report

M.S. van Esch
J.G.V. van Ramshorst

Delft University of Technology



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Challenge the future

The sewer system of urban Maputo

Final Report

By

M.S. van Esch (4225732)
J.G.V. van Ramshorst (4246764)

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Supervisors:	Prof. Dr. Ir. L.C. Rietveld (TU Delft) Dr. Ir. A. Marques Arsénio (TU Delft)
Co-supervisor:	Prof. N.P. Matsinhe (UEM, Mozambique)

Front page: a picture of the cement city

Summary

During three months information about the sewer system of Maputo was gathered, mostly at DNA, DAS, CRA, AdeM, AIAS and at the Municipality of Maputo. The information, consisting of reports, papers, maps, presentations and websites, was used to estimate the potential amount of wastewater in the sewer system of Urban Maputo. This wastewater could be available for reuse in Maputo, at the WWTP, being this the main purpose of the project "Sustainable freshwater supply in urbanizing Maputo, Mozambique" led by TU Delft, UNESCO-IHE and the Mozambican University UEM.

The sewer network consists of system one and system two. System one was built by the Portuguese in the 40s as a drainage system, but nowadays it functions as a combined sewer and it discharges directly into the bay. System two, built by DHV, a Dutch consultancy firm, in the 80s consists of sewer lines, a WWTP and two pumping stations. These pumping stations are also supposed to pump a part of the water of system one to the WWTP. However, because of sand in the pipes the pumping stations are not being operated.

The billed amount of drinking water was used to calculate the flow in systems one and two. These data were obtained per neighbourhood and multiplied by 0.8, a guideline in Maputo for the amount of drinking water ending up in the sewers. For the water flowing in the sewer network, three cases are estimated, the actual status, system two completely working and the total volume of system one and two. The actual flow into the WWTP is 3957 m^3/day with 20,665 m^3/day being directly discharged into the bay. If the pumping stations of system two were operating, 10,266 m^3/day would flow to the WWTP and 14,357 m^3/day would be directed into the bay (Figure 1). By measuring the amount of influent at the WWTP, using the existing Venturi meter, the calculations were validated. The measurements show a flow arriving to the WWTP in the order of the magnitude of the calculations .This influent is generated by approximately 38,000 users that are connected to the sewer system.

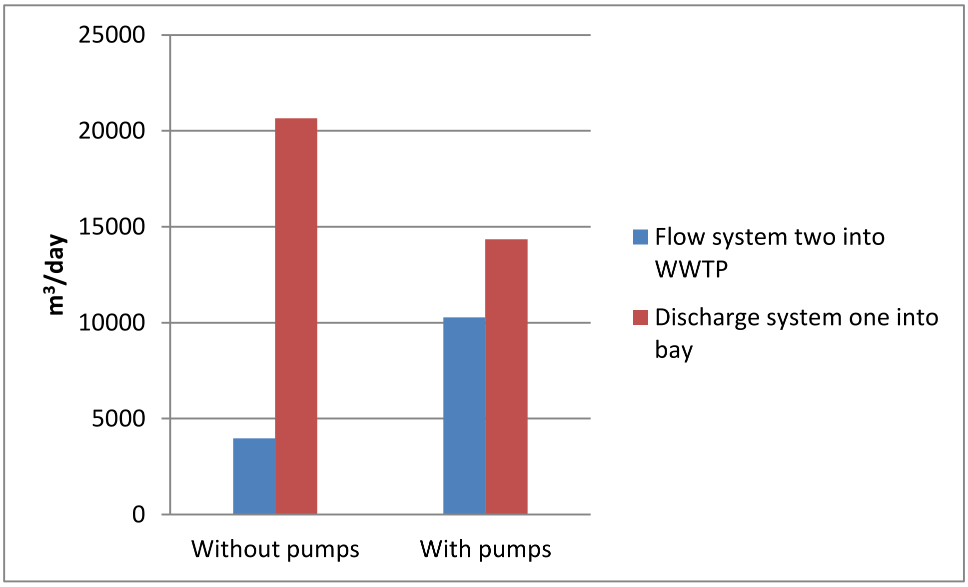

Figure 1: Wastewater flows in the sewer system for two different scenarios.

The sewer network of Maputo has a few critical parts which should be repaired as soon as possible, and better maintained in the future. First of all the pumping station of system two should be turned on. Before this is possible the sand in the sewers in front pumping station two must be removed and the pipes should stay clean. Sand and plastic bags ends up in the sewer system through drains or open manholes. To overcome clogging, drains and manholes have to be better maintained.

Another recommendation is to collect the wastewater being discharged by system one and convey it to the existing WWTP or to a new one. The municipality has plans for this but lacks financing.

All the water which is collected by system two is conveyed to the WWTP, but the WWTP is not functioning well. There is white slime in the effluent and colourful tarnish, which is a sign of bacteria being present in the effluent. The effluent is either directly used for irrigation of crops, which poses a risk for human health, or directed to the estuary.

At the moment there are detailed plans to introduce a sanitation fee, which is necessary to improve, operate and maintain the system. CRA has been working on introducing the fee for several years already and they expect to introduce it within the coming years.

Preface and acknowledgments

The report which you are about to read, was written for the project "Sustainable freshwater supply in urbanizing Maputo, Mozambique". More information about the project can be found at http://sustainablewatermz.weblog.tudelft.nl/. This project is led by the Delft University of Technology, Universidade Eduardo Mondlane (Mozambique) and UNESCO-IHE and is funded by NWO.

This report is written by Thijs van Esch and Justus van Ramshorst, both third-year Bachelor students Civil Engineering at the Delft University of Technology. The research was done as a part of their minor: a semester in the bachelor where you can freely choose courses and/or projects.

Our travel to Mozambique was funded by the Marc van Eekeren foundation from the Delft University of Technology. For this research we stayed in Maputo for three months. This was a very interesting period and we enjoyed our stay: we learned a lot about the sanitation in Mozambique and about Mozambican culture; we also experienced how it is to do research in a developing country. The period in Mozambique was enriching both for our study and for ourselves.

We would like to thank our supervisors for all the help and support given, Prof. Dr. ir. L.C. Rietveld (TU Delft), Dr. ir. A. Marques Arsénio (TU Delft), Prof. N.P. Matsinhe (UEM). We thank Dr. ir. M.W. Ertsen (TU Delft) for the help with the preparations.

We would like to thank Mário and Botelho at the Municipality (Department of Water and Sanitation), Robin van Loo (AdeM, VEI), Daúde Carimo (DNA), Raúl Mutevúie (DAS), Manuel Carrilho Alvarinho (CRA), Fernando Nhampossa (Royal Haskoning DHV), for the help and information they gave us. We would like to thank the Dutch Embassy for their interest in our project and for the support.

We would like to thank Teus Bronius and Carla Belmer, Kenneth Zimba and his family, for their hospitality and help in Maputo. We thank our flat mates in Maputo who helped us getting around in Maputo.

Last but not least we want to thank our families who supported us to do this project.

Finally, we hope this report will contribute to the improvement of the sanitation in Maputo.

Maputo, December 2014

Thijs van Esch
Justus van Ramshorst

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List of abbreviations

AdeM	Águas da Região de Maputo
AIAS	Administração de Infra-estruturas de Abastecimento de Água e Saneamento
CRA	Conselho de Regulação do Abastecimento de Água
DAS	Departamento de Água e Saneamento
DNA	Direcção Nacional de Águas
FIPAG	Fundo de Investimento e Património do Abastecimento de Água
MOPH	Ministério das Obras Públicas e Habitação
MZN	Mozambican Metical (local currency)
NGO	Non-governmental organisation
RHDHV	Royal Haskoning DHV
TU Delft	Delft University of Technology
UEM	Universidade Eduardo Mondlane
WSP	Water and Sanitation Program
WSUP	Water and Sanitation for the Urban Poor
WWTP	Wastewater Treatment Plant

1. Introduction

In this introduction we will present the project, the reason of our research and of course, the content of our research.

1.1. Introduction into the project

Maputo is the capital of Mozambique. The city is located in the south of Mozambique next to Maputo Bay (Figure 2). In 2010 there were 2.7 million people living in the metropolitan region, which comprises Maputo and Matola; nowadays 1.2 million live in Maputo alone, most of them in the peri-urban areas [1] [2]. Three million inhabitants are expected to live in this area in 2015 [3].

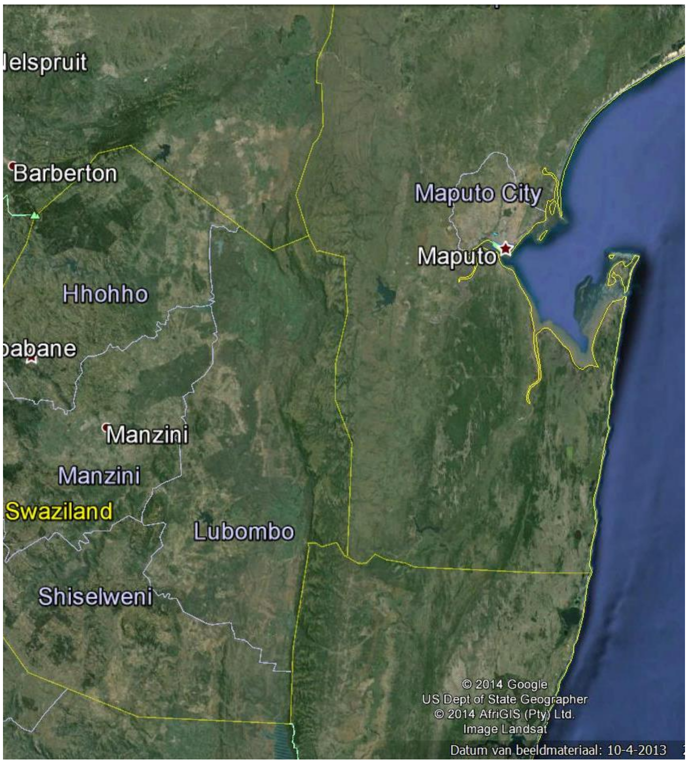

Figure 2: Location Maputo. Source: Google Earth.

In 2012 80% of the population in urban areas had access to drinking water [4]. The drinking water is produced from ground water and from the Umbulezi river, coming from a lake 40 kilometres away from the city. Recently a new source of water was needed. This source is 100 kilometres away from the city and is made by constructing the Corumana dam [5].

The water taken from the Umbulezi river is not enough for the total city [6]. Reuse could be a very good way for a new water supply, for example for irrigation. For this reason UNESCO-IHE, TU Delft and UEM started a project on water reuse entitled “Sustainable fresh water supply in urbanizing Maputo, Mozambique”. Within this project several students will investigate water reuse possibilities. The objective of this report is to quantify the amount of available wastewater in the sewer system. We will now take a closer look at the sewers of Maputo.

1.2. Introduction into the sewers of Cement City

The urban area of Maputo is known as Cement City and is covered by a sewer network. In the rest of the city there are only on-site systems, (improved) latrines and septic tanks.

The sewer network consists of two parts. One part, named system one was built by the Portuguese in the 40s as a drainage system. Nowadays it functions as a combined sewer because of National Decree 30/2003, article 128 and 132 [20].This obligates households to connect to a sewer if there is one in front of their house. Some of them are first connected to a septic tank. The system has several discharge points into the bay and estuary. This is one of the reasons why the bay is very polluted; others are sedimentation and solid waste dumping.

There is also a newer part, system two, built by the Dutch consultancy company DHV in the 80s and financed by the Dutch government. This system consists of a pipe network, two pumping stations and a WWTP. According to [1] and Mário (personal communication, Mário from the Municipality of Maputo, 31 October 2014, Maputo), these two pumping stations have not been working for several years. System two is connected to system one, but it is not known how much water they exchange. There is water entering the WWTP but it is not being treated well [7].

1.3. Research questions

The main goal of this research was to find out how much water is conveyed in the sewers of Maputo. This water could be reused, after treatment, if the system was operating well. The main research question of this report is:

What is the volume of wastewater in the sewer system of Urban Maputo?

To answer this question several sub questions will be answered first. These questions are:

1. *What are the sources of the waste water?*
2. *How much do these sources contribute to the system?*
3. *How is this waste water collected?*
4. *How much enters the WWTP and what happens to the rest?*
5. *What are critical parts of the system where much has to be improved*?

In addition to the main research questions there are two extra chapters in this report.

The first is about the institutional layout and Mozambican stakeholders. This is chapter two and it is entitled: “Constitutional Layout”. This extra chapter is not only for this project but also for the course *Water management research (CTB3415)* of TU Delft.

The second extra chapter is chapter seven, “Future Plans”, and it covers the plans for expanding the sewer system and introducing a tax.

2. Constitutional layout

This chapter shows many of the (governmental) organisations that are linked to the water and sanitation sector in Maputo and in Mozambique. The focus is on organisations which contribute to our project.

2.1. Governmental

There are several governmental institutions involved in drinking water and/or sanitation.

Drinking water & Sanitation

DNA (Direcção Nacional de Águas)

The National Water Directorate (DNA) is the body of the Ministry of Public Works and Housing (*Ministério das Obras Públicas e Habitação*, MOPH). DNA is responsible for every water related subject in Mozambique, including policy making, water supply and sanitation in urban and rural areas. They have several sub departments and they have created some companies like FIPAG and AIAS to manage all the water sectors [9], [10].

According to their own website [10] DNA‘s objectives are:

- Provide safe and reliable drinking water for everybody.
- Improve sanitation services to reduce the risk of water related diseases.
- Reduce the vulnerability to floods and droughts by better coordination and planning.
- Promote peace and regional integration and taking care of water resources for development by joint management of shared water basins.

AIAS (Administração de Infra-estruturas de Água e Saneamento)

AIAS was established by DNA in 2009. According to [8] AIAS is responsible for, and asset owner of the sanitation system in Maputo as well as the rest of Mozambique. They are also responsible for drinking water supply in middle and large cities and villages in Mozambique.

CRA (Conselho de Regulação do Abastecimento de Água)

In Portuguese CRA stands for Water Supply Regulation Council. CRA regulates the water services regarding to tariffs, quality of service and network expansion programmes. Tariffs on drinking water need to be approved by CRA. For many years CRA has been trying to introduce a sanitation fee in Maputo. The people who use the sewer system, or are in the area of the sewer system, will pay for it as a percentage on their drinking water bill.

DAS (Departamento de Água e Saneamento)

DAS is part of DNA and they have the mandate to plan, develop and monitor activities and projects. They are focused on sanitation and sewers in Mozambique.

Sanitation

Municipality of Maputo

The municipality of Maputo is responsible for the sanitation in the city. The municipality has not enough manpower nor funds to do this alone [11]. They have a special department with an own office for the sanitation.

Drinking water

FIPAG (Fundo de Investimento e Património do Abastecimento de Água)

FIPAG is an autonomous public asset holding company for the five major cities. FIPAG is an implementing agency for water supply programs in large urban area. It is established in 1998 as a public entity, to act as an investment and asset holding organisation for five city water supply systems (Maputo, Beira, Quelimane, Nampula and Pemba) [13].
The specific responsibilities of FIPAG are:

- Investment and financial management for rehabilitation and expansion of water supply assets;
- Maximize efficiency and return of existing assets
- Contract management, monitoring and enforcement of the contractual obligations of private operators.

AdeM (Águas da Região de Maputo)

Since 1999, AdM was owned by some Mozambican parties, joined as MAZI, the French SAUR and the Portuguese AdP (Águas de Portugal). In 2002 the French shareholder withdrew and sold his part to AdP. In late 2010 AdP sold his part to FIPAG and FIPAG became main shareholder.

AdeM is the successor of AdM (Águas de Moçambique) and was established by FIPAG in 2011. AdeM is leasing the drinking water system of Maputo from FIPAG. This means AdeM is responsible for operating the drinking water system [3] and [12].

2.2. Non-Governmental

There are also non-governmental organisations involved in the project. These organisations contain engineering firms, investors and some others.

Pamodzi

Pamodzi is a Mozambican NGO that aims to improve sanitation standards of people living in poor areas. They build eco latrines and educate inhabitants in the neighbourhoods about hygiene. Two students of the TU Delft worked with Pamodzi to investigate the health risks associated with using urine as fertilizer [14].

Royal Haskoning DHV

RHDHV is a Dutch company which is active in Mozambique for many years. They also have an office in Maputo. In the 80s RHDHV, then called DHV, built sewer system two in Maputo. SEED, was a part of DHV in Mozambique. Until 2011 SEED wrote, together with WSUP, strategic plans for the sanitation of Maputo.

Salomon

Salomon is a consultancy firm based in Maputo, founded in 2001. They work in Southern Africa and their mission consists of two parts [15]. Part one is "the promotion of efficient, equitative and sustainable use, utilization and management of water and natural resources in Southern Africa." Part two is "the promotion of Water Resources and Environmental Management as a priority to governments, private entities and institutions in Southern Africa."

Prof. Nelson Matsinhe and Prof. Dinis Juízo work for Salomon and are two of the four partners of the company. Nelson Matsinhe and Dinis Juízo are also cooperating within the project. They help students who are researching in Maputo and they are the local contacts from UEM.

WSUP (Water and sanitation for the Urban Poor)

WSUP is a multi-sector partnership (Unilever, Care, Thames Water, WaterAid, Borealis, Cranfield University, Vitens Evides International and Halcrow) that aims at improving the lives of urban poor in developing countries. They are active in the field of drinking water and sanitation. They are mainly focusing on on-site systems, but in Maputo they also did research on the off-site system.

Water Aid

Water Aid was established in 1981 as a charitable trust. They are funded by governments, companies and civilians. The money is used to bring water and sanitation services to places where there is none. Their four global goals are [16]:

1. Promote and secure poor people‘s rights and access to safe water, improved hygiene and sanitation.
2. Support governments and service providers in developing their capacity to deliver safe water, improved hygiene and sanitation.
3. Advocate for the essential role of safe water, improved hygiene and sanitation in human development.
4. Further develop as an effective global organisation recognized as a leader in our field and for living our values

In Mozambique last year they connected 78,000 people to safe drinking water and 71,000 people to improved sanitation services. Water Aid also financed the construction of ecological latrines in Maputo. The urine of these ecological latrines is used by farmers for fertilizer [14].

WE Consult

We Consult started working in Mozambique in 2003. They do consultancy work in the field of water and sanitation. They did eight projects in and around the city of Maputo. One which is related to our study is the baseline study done for WSUP [17].

World Bank

The World Bank is a big player in Maputo. Not only do they subsidise projects, but they also do research which contributes to the local knowledge on water. A big project which they are financing the water line from Corumana Dam for FIPAG [5] and a new drinking water supply network in the North of Maputo. The part of World Bank doing research in this field is Water and Sanitation Program (WSP).

Recently World Bank became more involved in the project “Sustainable freshwater supply in urbanizing Maputo, Mozambique”. They provide support and finance human resources for a research to fill in the knowledge gabs about the faecal sludge management service chain in Maputo. For this research a household survey was set up and was supervised by a master student.

Academia

Professors and researchers from the educational institutions below, form the management team of the project "Sustainable freshwater supply in urbanizing Maputo, Mozambique". The institutions have several bachelor, master and PhD students working in Maputo.

Delft University of Technology (TU Delft)

TU Delft is linked to Mozambique through projects since 1987. They guide the project and they send bachelor and master students to do research for the project.

Universidade Eduardo Mondlane (UEM)

UEM is the biggest university in Maputo, Mozambique. They have two Professors assisting students in Mozambique (see part about Salomon). Also there will be four PhD students working on the project.

UNESCO-IHE

According to their website [18], UNESCO-IHE is the largest graduate water education facility in the world. They offer master and PhD degrees.

3. Materials and Methods

To answer our main research-, and sub questions, information was needed. To collect these data we made a list with information needed and the company or organisation where to find it (Appendix A).

The population and density data for each neighbourhood from [1] is used to calculate the number of users and the area covered by sewer system, showed in Table 1 and Table 2. The number of users, for each neighbourhood, multiplied with the percentage of water going into system one or two, gives the number of users for each situation is. To calculate the area covered by the system, the population and density (pers/ha) for each neighbourhood is used. Dividing the population by the density gives the hectares for each neighbourhood. Combining this again with the percentage of water going into system one or two, gives the area for each situation. To verify the size of the total area, the size of the system is also measured with Google Earth (Table 3).

To calculate the flows, we used the drinking water data from AdeM [19]. This drinking water data was available per neighbourhood (bairro, in Portuguese), per month. We used the data collected from November 2013 until October 2014, so that we have one year. The percentage of water going into system one and the percentage of water going into system two were estimated per neighbourhood. In an Excel sheet the following flows were calculated:

- The incoming flow at the WWTP if system one and two would be conveyed to the WWTP.
- The incoming flow at the WWTP if the pumping stations would work.
- The incoming flow at the WWTP with the current situation.
- The flow out of the discharges in total with the current situation.

The average flow in cubic meters per day was calculated. These values were multiplied by 0.8 since this is the guideline in Maputo for the percentage of drinking water which comes into the sewers.

To validate the flow calculated measurements were done at the WWTP using a Venturi meter. However, the bottom of the level meter is broken (Figure 3) and eventually the measurements were done by measuring the height of the water (Figure 4) and comparing this to the graph of the Venturi meter (Figure 5), which shows the relation between the height of the water and the flow into the WWTP [20].

Figure 3: Broken level meter. The meter would convert directly the water height into water flow (L/s).

Figure 4: Materials used to measure the water height.

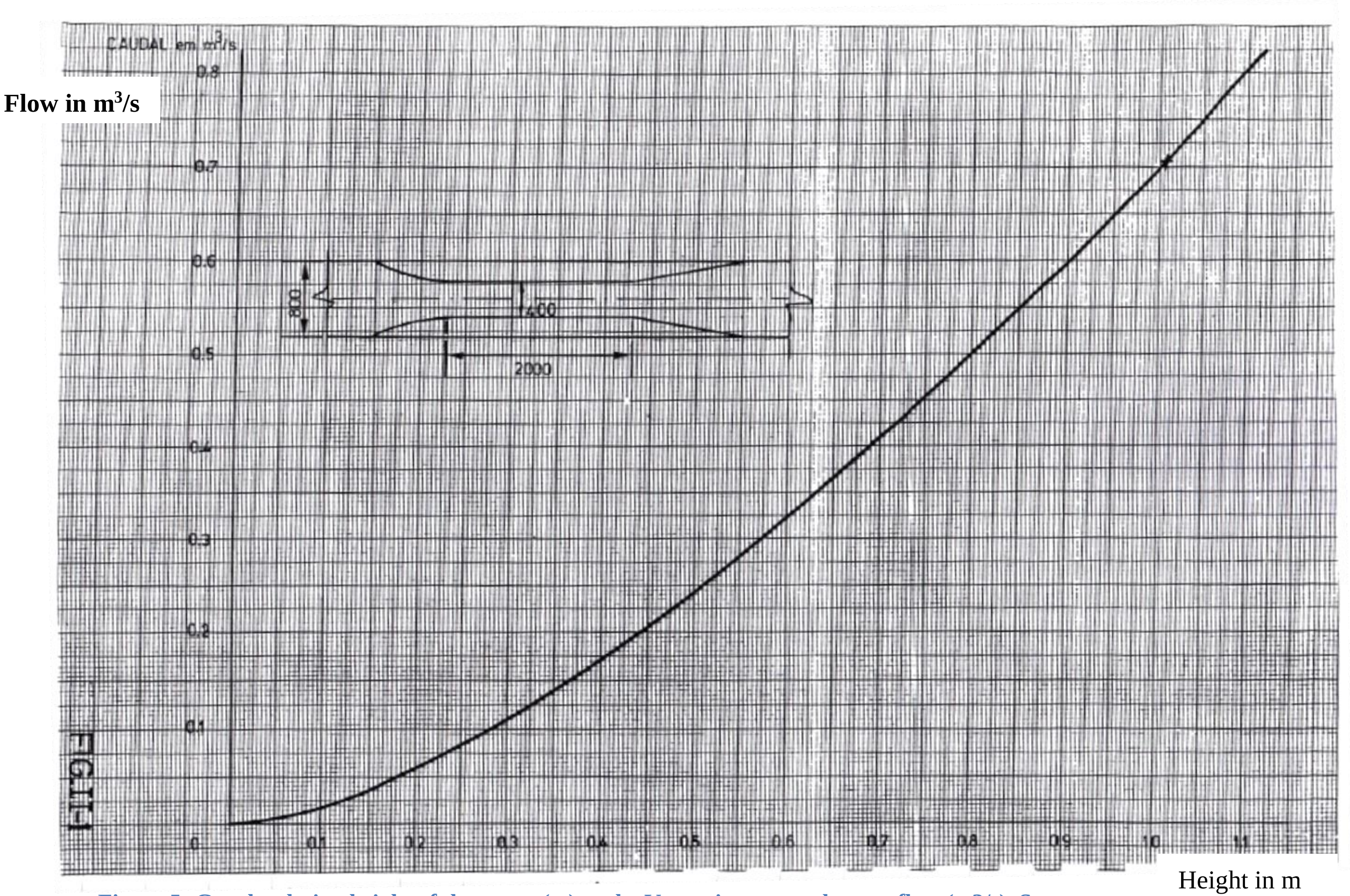

Figure 5: Graph relating height of the water (m) at the Venturi meter and water flow (m3/s). Source [20].

4. Results

4.1. Layout of the system

As said in the introduction, the sewer system consists of two parts. System one was built in 1948 by the Portuguese as a drainage system. Nowadays it functions as a combined sewer because of National Decree 30/2003, article 128 and 132 [21]. The Decree makes the connection of households to the sanitation network mandatory. This is also if the pipe is not a sewer but a drain. The southern part of Cement City is connected to system one, the northern part to system two. System two was built by DHV in the 80s. It was designed for 90,000 people [22] but according to [2] it is only serving 21,000 people at the moment, because the pumps are not working. Figure 6 depicts the layout of the system and Figure 7 shows the location of the system.

In Table 1 and Table 2 is given the number of inhabitants using the sewers for several scenarios and the area covered for each scenario. System two without pumps is the actual situation. Table 3 is to verify the calculated values in Table 2.

In Table 4 are shown details about system one and two; this is based on [23] and [24].

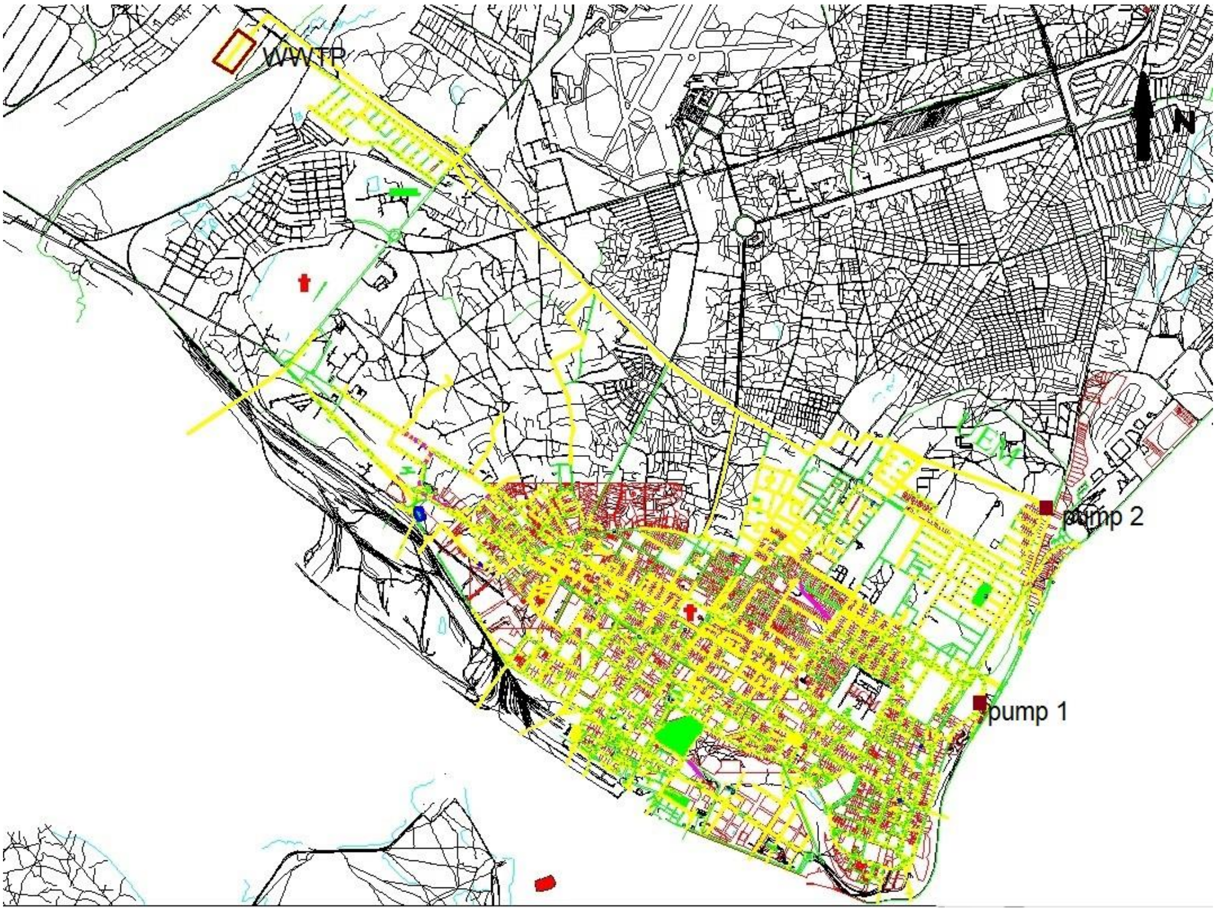

Figure 6: AutoCAD drawing of the sewer network of Maputo. Pumping stations one and two and the WWTP are indicated. Source [27].

Figure 7: Aerial photograph of Maputo. This covers the same area as Figure 6. The location of pumping stations one and two and of the WWTP are indicated. Source: Google Earth.

Table 1: Number of water users per neighbourhood for each scenario.

Neighbourhood	Population (2007)	System two, without pumps (inhabitants)	System two, with pumps (inhabitants)	System one (inhabitants)	System one+two (inhabitants)
Alto Maé A	8800	5280	5280	3520	8800
Alto Maé B	12416	0	0	12416	12416
Central A	10679	5340	8009	2670	10679
Central B	11375	0	0	11375	11375
Central C	8352	0	0	8352	8352
Coop	5639	0	5639	0	5639
Malhangalene A	6618	3971	6618	0	6618
Malhangalene B	17348	17348	17348	0	17348
Polana Cimento A	7807	0	1561	6246	7807
Polana Cimento B	8131	0	2683	5448	8131
Sommerschield	9040	0	6057	2983	9040
Malanga	17276	0	0	17276	17276
Jardim	12720	6360	6360	6360	12720
Total population	**136201**	**38298**	**59556**	**76645**	**136201**

Table 2: Area in hectares (ha) per neighbourhood for each scenario.

Neighbourhood	Density (pers/ha)	Population (2007)	Area (ha)	System two, without pumps (ha)	System two, with pumps (ha)	System one (ha)	System one+two (ha)
Alto Maé A	189	8800	47	28	28	19	47
Alto Maé B	107	12416	116	0	0	116	116
Central A	189	10679	57	28	42	14	57
Central B	201	11375	57	0	0	57	57
Central C	40	8352	209	0	0	209	209
Coop	85	5639	66	0	66	0	66
Malhangalene A	142	6618	47	28	47	0	47
Malhangalene B	180	17348	96	96	96	0	96
Polana Cimento A	73	7807	107	0	21	86	107
Polana Cimento B	106	8131	77	0	25	51	77
Sommerschield	21	9040	430	0	288	142	430
Malanga	115	17276	150	0	0	150	150
Jardim	61	12720	209	104	104	104	209
Total hectares			**1667**	**285**	**719**	**948**	**1667**

Table 3: Total surface area in hectares of the area covered by systems one and two.

	Area (ha)
Total calculated	1667
Total based on Google Earth	1545

Table 4: List with details of systems one and two.

	System one	System two
Pipes	70 km [23 and 24]; of which: 56 km< 800 mm, and 13 km > 800 mm [24]	12,6 km [23]
Aqueducts	--	1.5 km [23]
Canals	--	16 km covered canals [23 and 24] 0.62 km rectangular canals [24] 3,4 km uncovered canals [23]
Manholes	2500 [23 and 24]	350 manholes [23]
Inlet structure	5000 [23 and 24]	--
Gutters	--	670 [23]
Pumps	--	2 [23 and 24]

4.2. Sources of wastewater

Drinking water

The main water source for the system is the water delivered by AdeM. During the dry season the main water source for system one is the fresh water, but in the rainy season the drains of the system will also be filled with rain water.

The drinking water delivery in the data of AdeM [19] is divided in 5 main users/categories:

1. Domestic water is used by citizens in their home,
2. Public water is used by, for example, hospitals and schools,
3. Commercial water is used by shops, restaurants and hotels,
4. Industrial water is used by factories and other (smaller) industries,
5. Municipal water is the water used in Municipal buildings.

How much water is contributed per main category is shown in Table 5. For the average each month and a year average per neighbourhood see the Appendix B.

Table 5: volume of drinking water consumed in Maputo per type of user in one year.

Type of user	m^3	%
Domestic	6,674,052.60	55.58
Public	1,503,215.00	12.52
Commercial and services	2,998,976.60	24.97
Industrial	829,468.00	6.91
Municipal	2,802.00	0.02
Total	12,008,514.20	100

Rainwater

Maputo has a short rainy season from October until March [25]. The average precipitation each month is shown in Appendix C. In this period of the year, Maputo can have problems with flooding in Cement City [26] and [13]. A part of this floodwater in Downtown Maputo should be discharged through the system one. How much the rain contributes to the system is not known, since there was no data available. The downfall is short but intense, with the effect of a peak in the sewers. How big this peak is, is not known.

4.3. Flow analysis

On the measuring day we measured the influent in the WWTP each fifteen minutes (Figure 8). For the raw data, please check Appendix D.

In Table 6 are the results of the calculations for the dry weather flow, the average values over a year. There is a little error, because of the results being a calculated average, based on the billed amount of drinking water.

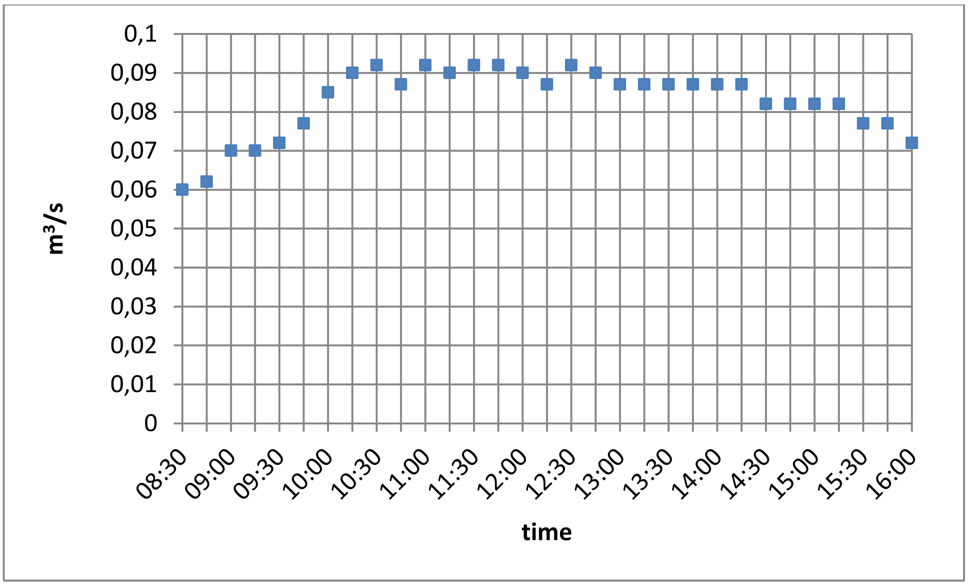

Figure 8: Measurement wastewater flow arriving at the WWTP during one day. Measurements were made with 15 minutes interval.

Table 6: Results of the calculations of flow in the sewer system.

	All neighbourhoods	Neighbourhoods covered by system two (connected to WWTP)	Neighbourhoods covered by system two (connected to WWTP if the pumps work)	Neighbourhoods covered by system one (discharging into bay)	Neighbourhoods covered by system one (discharging into bay if the pumps work)
Billed drinking water (m^3/day)	30761	4947	12832	25832	17946
Produced wastewater (m^3/day)	24609	3957	10266	20665	14357

4.4. Critical parts

Pumps

Sewer system two in Maputo contains two pumping stations. Number one is located near the Polana Hotel along the hillside and number two is located on the corner of the Rua do Arcebispado with Julius Nyerere Avenue (Figure 7, Figure 10). In many reports is mentioned that the pumps are not working [1] and [2]. According to SEED the pumps are not operating since 2008 [1].

The actual status of the pumping stations was told us by an engineer of the Municipality, during a visit to the pumping stations (personal communication, Mário from the Municipality of Maputo, 31 October 2014, Maputo). In 2008 problems occurred at pumping station two because of an electrical meltdown (Figure 9). After fixing the electrical parts, the municipality noticed an overload of sand in pumping station two and in the sewer system in front of the pump. The amount of sand in the sewer can be destructive for the pumps. At this time the overload of sand is still the reason that pumping station two is not switched on, since until now it has not been cleaned. In the meantime pumping station two is renewed and everything should work. Pumping station two contains three pumps, of which one is always switched on and a second pump is turned on in case of high influent. The capacity of the pumps is unknown.

Nevertheless, there is still influent coming from uphill by the gravity sewer in front of pumping station two. All this influent is flowing into the bay through a drainage system next to the sewers. There is a connection, to the drainage system, made in front of pumping station two. This is necessary because the overflow upstream is clogged with sand. The sewage water is not transported by trucks to the WWTP as mentioned in [1] and [2].

Pumping station one collects wastewater in the area around and pumps this into a gravity pipeline which flows to pumping station two. This is the reason why pumping station one is also switched off, just like pumping station two. Instead of pumping water unnecessary to the overflow near pumping station two, the overflow in pumping station one is used. This means all the water in front of pumping station two is directed into the bay. This means that at the moment, only the gravity part of system two is directed to the WWTP. This area is coloured red in this Figure 10.

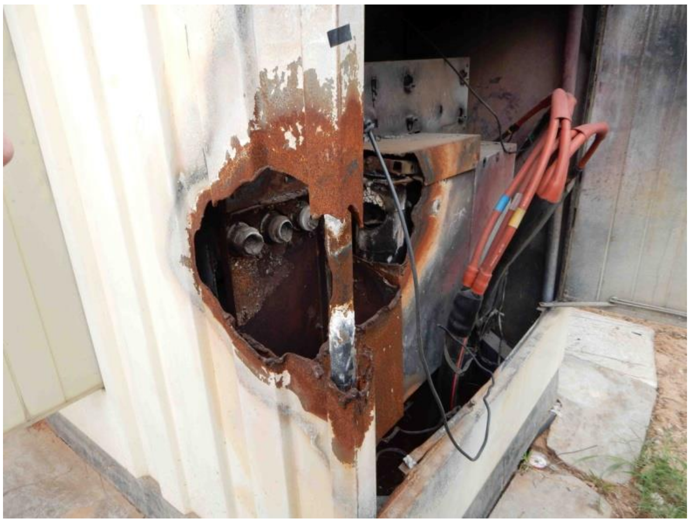

Figure 9: Meltdown of electrical system of pumping station two.

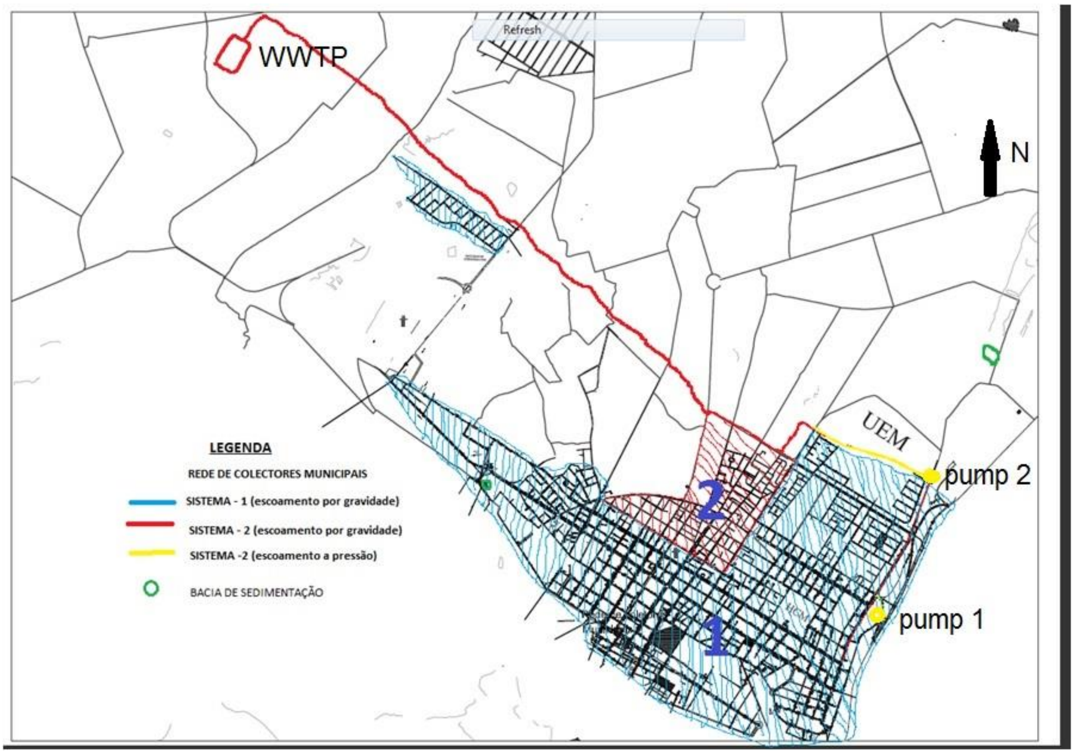

Figure 10: Drawing with system one (light blue) and system two (gravity flow in red and pressurized flow in yellow). This drawing covers approximately the same area as Figure 6 and Figure 7. The location of pumping stations 1 and two and of the WWTP are indicated. Source [23].

Wastewater treatment plant (WWTP)

Another critical part in the sewer system is the WWTP. The WWTP is not working well [7]. The bar screen is filled with garbage, blocking the stream. As a result all the wastewater flows through the bypass (Figure 11). The lagoons of the WWTP are covered for about 80% with plants (Figure 12). The effluent, which exits the WWTP, is clear but not clean and this unhealthy water is used for irrigation by farmers, who take out the water from the canal, without protective clothing. There is an average flow of 3,957 m^3/day into the WWTP (Table 6).

Figure 11: Photo of bar-screen at the entrance of the WWTP. Since the screen is clogged by debries, the water by-passes the screen through the over-flow.

Figure 12: Plants, garbage and car oil covering the lagoon.

Discharges into the bay

There is an interesting plan from the Municipality to collect all the water from the discharges and direct them to a new WWTP, which would be built in the Infulene Valley. A part of this new WWTP would be only for faecal sludge. There are 22 discharges into the bay [27] (Figure 13). About 1/3 of the wastewater in system one could be directed to system two, but then the pumps must be working, so at this moment, all of system one is discharging in the bay. Together these discharges produce an average waste water flow of 20,665 m^3/day (Table 6). If all this water could be collected, there would be a lot more to reuse, and the bay will be less polluted.

Figure 13: Discharge of untreated sewer into the bay.

Manholes

Blocked pipes and manholes are a problem in Maputo which should be taken into account. Many manholes are missing their covers. This in combination with poor solid-waste management, results in sand and solid-waste being deposited into the manholes. In all open manholes you can see garbage, mainly plastic bags and bottles, sometimes blocking the pipe. (Figure 14). Also the drain entrances are full with garbage. During the rainy season, some of the manholes and drains are cleaned. The garbage is taken out of the drains and manholes and is put next to it on a big pile. These piles are not always taken away immediately, and some garbage disappears in the manhole or drain again.

The only way to solve this problem is, in the case of manholes, make sure that every hole has a good cover, one that will not be stolen or will not disappear. In the case of the drains it is harder to control, because they have to be open. The system would be improved by a more advanced solid-waste management in the city and more awareness from its citizens. This would improve the wastewater flow and also the use of the capacity of the drains.

Figure 14: Uncovered manhole in the streets of Maputo.

5. Discussion

In Section 4.1 the number of users of the sewer network is estimated for three situations, system two without pumps, system two with pumps and system one and two. When these results are compared to [1] and [2], some differences are found. According to [1] systems one and two cover a total population of roughly 315,000 inhabitants. This is highly unlikely because the number of people living in Cement City, the main area covered by system one and two, was 154,000 inhabitants in 2007 [1]. This makes the result of 136,201 inhabitants more convincing. Regarding the actual situation, the results from Section 4.1 show a higher number of inhabitants served by system two, compared to [2] (38,298 compared to 21,000, taking into account an average dry water flow of 3,957 m^3/day. According to these results, a population of 21,000 would use 189 lppd. This amount of water use is for a developing country rather unlikely. A population of 38,298 on the other hand would use 104 lppd, which is much more plausible.

The areas calculated in Section 4.1 are based on the population and the density (pers/ha) of the population in 2007 [1]. Furthermore the estimated percentages of neighbourhoods covered by the system are used to estimate the percentages of population and area contributing to the system, per neighbourhood. These areas are compared to areas calculated with Google Earth. These calculations are rough, but it shows that the first calculations are in the same order, thus trustworthy. The area is given in Table 3.

In Section 4.3 a calculation of the average flow is done. For this the data from AdeM was used. These data is the total billed drinking water per neighbourhood. There is leakage in the system and of course not everything of the drinking water ends up in the sewers. A general guide line used in Maputo for this calculation is to multiply the billed amount of drinking water by 0.8. Using the billed amount reduces the losses by leakage in the drinking water system. However there are some flow meters at households which are measuring the flow in two ways, and they just add up the amount of water. The actual consumed amount of water might be less because of this. There can also be illegal connections to the drinking water system. If these people use the sewers, there might be a higher flow than the calculation.

If we compare the calculation of the average flow into the WWTP with the measurements we see a big difference. We did not measure 24 hours, and it is not the exact amount, but it comes close. If the average flow into the WWTP is 3,957 m^3/day, it would mean that the night before our measurements would be no flow, or not much. It might be that the results of the measurement day were far higher than an average day. This is unlikely because it was a dry weather discharge. Another explanation is that there is extra water leaking into the sewer system, for instance ground water. This is possible because it is an old system. It is also possible that there are unknown connections to the system or that a part of system one is flowing into system two and is conveyed to the WWTP.

Section 4.3 furthermore shows the measurements of the influent at the wastewater WWTP in the Infulene valley. These measurements give an idea of the flow into the wastewater treatment plant during a dry day. With a proper level meter on site, instead of measuring with a wooden stick and a tape line, the measurement could have been more accurate. This measurement was done with an accuracy of 0.5 cm. With the help of the graph (Figure 5) this was converted to flow. No technical equipment was used for this. With this way of measuring, measuring errors easily occur.

6. Conclusion

In this conclusion we first recap all our research questions before answering them.

What is the volume of waste water in the sewer system of Urban Maputo?

To answer this question several sub questions will be answered first. These questions are:

6. *What are the sources of the waste water?*
7. *How much do these sources contribute to the system?*
8. *How is this waste water collected?*
9. *How much enters the WWTP and what happens to the rest?*
10. *What are critical parts of the system where much has to be improved*?

The wastewater network in Maputo has two sources, drinking water and rainwater. During the dry season from April until October, drinking water is the only source of waste water. In the rain season, rainwater contributes as well during rainy days. The drinking water is used by multiple users, before ending up in the sewers. These users are divided into domestic, public, commercial and industrial users and the municipality.

Only for the drinking water it is possible to tell how much the contribution to the sewer system is, because these data are available. The biggest source of wastewater from drinking water is domestic use with 55.6%, followed by commercial and public use, 25% and 12.5%. The industry uses 6.9% and the municipality uses an insignificant amount of water. The contribution of the rain water varies daily and there it is hard to find data showing the intensity of the rain shower.

The waste water collection in Maputo is done by two systems, system one and system two, both located in urban Maputo. System one was built in 1948 as a drainage system and system two was built as a sewer system in the 80s. The big difference between these systems is that system one is changed into a mixed system and system two is still a separated system. This means that the discharge of system two is more or less the same during the year, even during the rainy season. System one, however, collects sewage water through connections of houses and other buildings, but also collects rain water through drains.

System two is the only part which is directly connected to the WWTP. At the moment all the wastewater in system one is directed into the bay because due to clogged pipes the two pumps of system two are not switched on. This results in more wastewater ending up in the bay. According to the estimations (Section 4.3), at this moment 3,957 m^3/day is transported to the wastewater treatment plant. If the pumps from system two would work, this would be 10,266 m^3/day. The estimations show a wastewater flow into the bay of 20,665 m^3/day. With the pumps working system one would still pollute the bay with 14,357 m^3/day of untreated wastewater.

The system could be improved by taking care of the four critical parts in the system. The first solution would be to clean the clogged pipes near pumping station two and make sure less sand will be entering the system. This will expand the flow to the WWTP with approximately 6,309 m^3/day. The second critical parts are the manholes and drains. If the municipality can make sure that there is not much garbage and sand entering the sewers, the capacity of the system will improve. Third, the discharge of system one should be taken into account. The municipality has plans to collect all the waste water and to treat this. This would be a great improvement to the ecological situation of the bay. Last but not least the operation of the WWTP has to be improved, which [7] already pointed out. The effluent has not the quality as it should have according to the regulations and meanwhile is used for irrigation of the crops in the Infulene valley.

Finally, the answer the main question is the volume of the wastewater in the system is about 25,000 m^3/day. Unfortunately this water is not all available for reuse at the moment, but it can be available in the future.

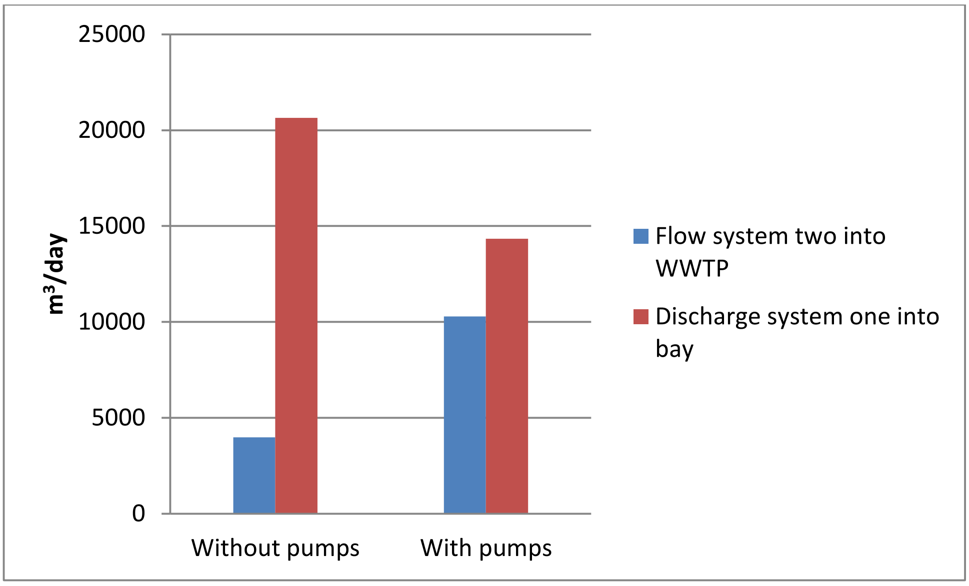

Figure 1: Wastewater flows in the sewer system for two different scenarios.

7. Future plans for Maputo

This is an extra chapter on the future for Maputo. During our research we found out that Maputo is changing, and that there will be changes made in the field of sanitation as well. Some of them very soon, others will take longer.

7.1. Sanitation Fee

At the moment the maintenance of the sewer system and the WWTP needs to be financed by the Municipality. It cannot be financed by the sanitation department, since this department does not generate any income. According to [28] this fact is the reason for limited sanitation services. Another reason is that sanitation is not the priority for the government in comparison to drinking water.

It is better to be able to maintain the system from the revenue of the system. This can be done by collecting a fee from the people who use the sanitation services.

CRA will be responsible for the implementation of the fee and they asked WSUP to do a study to the implementation of the fee [28].The hard part is that if they introduce the tariff, the situation has to change immediately. The Municipality must work on the sewer system, even though there might not be enough money for that, after just introducing the fee.

There were two options in report [28]. Option A was to introduce a flat tariff (in MZN per household), and option B to introduce a tariff that is proportional to the drinking water bill (percentage per household) (Figure 15). Option B is said to be the best [28].

Irrespective of the chosen option, some people will have to pay for sanitation services: the fee will be paid by people connected to the sewer, and people who use more than 10 m^3 per month. Furthermore, industries, commercial and municipal users will also pay. Option B is expected to generate a cash flow of 165 million MZN and a Net Present Value of 38 million MZN. The cash flow is about the half of the total budget of AIAS (364 million MZN) (personal communication, Joep Vonk (AIAS), 15 December 2014, Maputo)

According to the plan the tariff will be introduced in three phases. Phase I is introduction of the tariff, and the beginning of the expansion of the services. Phase II is the scale-up, people will pay more for the expended services. In phase III the expansion of the services must be done, and the final tariff will be paid. The time span of these phases is fifteen years.

There is one thing about the introduction which can cause some trouble. There will be users with on-site systems (e.g. septic tanks), who use more than 10 m^3 and therefore, will have to pay for the sanitation. Within this calculations is assumed that these people will have enough money, since they use more water than average. They do not use the sewers, have to pay themselves to empty their septic tank, and they still have to pay a fee for the sanitation. On the other hand, they also use the WWTP and introducing different values for this group of users may cause trouble with collecting the money.

As said by [28] the Municipality, AIAS, AdeM (the institution that will collect the fee through the drinking water bill) and CRA must work together better to successfully introduce this fee and to expand the services. If they manage to do this, it will be a big improvement for the sewers of Maputo and for the lives and health of the inhabitants.

	PHASE I: TRANSITORY	PHASE II: SCALE-UP	PHASE III: SERVICES FOR ALL
OPTION A: FLAT TARIFF			
Class A-i	20	50	70
Class A-ii	20	50	70
Class A-iii	200	500	700
Class A-iv	400	1,000	1,400
Class A-v	-	-	-
Class B-i	20	35	40
Class B-ii	-	20	35
Class B-iii	200	350	400
Class B-iv	400	700	800
Class B-v	-	-	-
Class C	-	-	-
OPTION B: PERCENTAGE OF WATER BILL TARIFF			
Class A-i	10%	25%	30%
Class A-ii	10%	25%	30%
Class A-iii	10%	25%	30%
Class A-iv	10%	25%	30%
Class A-v	-	-	-
Class B-i	10%	15%	20%
Class B-ii		10%	15%
Class B-iii	10%	20%	30%
Class B-iv	10%	20%	30%
Class B-v	-	-	-
Class C	-	-	-

Figure 15: **Options A and B for the sanitation fee according to [28]. Class A: AdeM customers in sewered areas. Class B: AdeM customers in non-sewered areas. Class C: All customers served by private water operators (POPs). These categories are further subdivided to increase equity, where the suffix "i" indicates a domestic customer consuming over 10 m^3 of water per month; "ii" indicates a domestic customer consuming under 10 m^3 per month; "iii" indicates commercial, non-metered, public and municipal customers; "iv" indicates an industrial consumer; finally, "v" indicates a customer connected to a tap stand" [28].**

7.2. Sewer system three

New plans which will take longer to realise are the plans of sewer system three, combined with a second WWTP at the Infulene – WWTP two. The drawings and plans of the new planned system are ready but financing is insufficient.

The plan is basically to collect all the water from the discharges from system one, and convey them to the WWTP (Figure 16) [29]. This WWTP is not the current one but has to be built. The current sewer system has to be expanded (the yellow parts in the picture). The current WWTP will also be expanded. There might even come a special part for faecal sludge (personal communication, Municipality of Maputo, 31 October 2014, Maputo).

This plan would be a big improvement for Maputo. They would be able to expand the current system more, because the treatment capacity will be increased. This would require further study. A second improvement would be that the bay would be less polluted.

The down side of these plans is that a big part of the small farms in the Infulene have to be relocated. At this moment the most of the vegetables in the local markets of Maputo come from the farms in Infulene valley. The construction of a new WWTP and the expansion of the current one would take about 3 times the space of the current WWTP. The farmers should be relocated. Just removing the farms might give a lack of food on the local markets and increase the prices of vegetables and fruits even more.

Figure 16: Schematic drawing of projected system three.

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9. Appendices

Appendix A	Checklist
Appendix B	Result measuring day
Appendix C	Weather details
Appendix D	Flow per month

Appendix A

List with information needed and the company or organisation where to find it.

This checklist contains the information we need to answer the research questions.

Item	Which question	Where
Map of the network	1,3,5	Municipality/DHV.DNA
Number of connections	1,2,4	Municipality/DNA/AIAS
Septic tanks connections	2,3	Locals/Municipality/DAS
Flow rates	2,4,5	DNA
How is the system mixed/ system 1 vs system 2	4,5	DHV/DNA(Drainage office)/DAS
How many days does it operates	4,5	DNA/Municipality
How does the network behave when it rains	1,2,3,4,5	DNA/Municipality/Locals
What are the building materials and how old are they	5	AIAS/DNA
Have parts of the network been replaced, is there a program for replacement	5	Municipality/AIAS
What are the locations of the overflows and how much do they overflow in a year	4,5	DHV/AIAS/Locals/Municipality
When do the pomps work, what is there average power	3,4,5	Municipality/DNA/DHV
Are there parts in the network which are broken and not fixed, not cleaned or known for leakage	4,5	Municipality/DNA
Is there some kind of tax for a wastewater network connection	5	Municipality

Appendix B

Flow of wastewater arriving at the WWTP during one day. The depth of the water at the Venturi meter was measured every 15 minutes. The depth was converted to m^3/s using the graph depicted in Figure 5.

Time	Depth	m^3/s
8:30	20,5	0,06
8:45	21	0,062
9:00	22,5	0,07
9:15	22,5	0,07
9:30	23	0,072
9:45	24	0,077
10:00	25,5	0,085
10:15	26,5	0,09
10:30	27	0,092
10:45	26	0,087
11:00	27	0,092
11:15	26,5	0,09
11:30	27	0,092
11:45	27	0,092
12:00	26,5	0,09
12:15	26	0,087
12:30	27	0,092
12:45	26,5	0,09
13:00	26	0,087
13:15	26	0,087
13:30	26	0,087
13:45	26	0,087
14:00	26	0,087
14:15	26	0,087
14:30	25	0,082
14:45	25	0,082
15:00	25	0,082
15:15	25	0,082
15:30	24	0,077
15:45	24	0,077
16:00	23	0,072

Appendix C

Climate data for the city of Maputo.

Climate data for Maputo													[hide]
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	43 (109)	39 (102)	40 (104)	39 (102)	38 (100)	34 (93)	36 (97)	39 (102)	46 (115)	45 (113)	44 (111)	44 (111)	46 (115)
Average high °C (°F)	29.9 (85.8)	29.6 (85.3)	29.3 (84.7)	27.8 (82)	26.4 (79.5)	24.6 (76.3)	24.4 (75.9)	25.3 (77.5)	26.1 (79)	26.5 (79.7)	27.4 (81.3)	29.1 (84.4)	27.2 (80.96)
Daily mean °C (°F)	26.1 (79)	26.0 (78.8)	25.4 (77.7)	23.6 (74.5)	21.6 (70.9)	19.5 (67.1)	19.3 (66.7)	20.4 (68.7)	21.7 (71.1)	22.4 (72.3)	23.6 (74.5)	25.3 (77.5)	22.91 (73.23)
Average low °C (°F)	22.3 (72.1)	22.3 (72.1)	21.5 (70.7)	19.4 (66.9)	16.8 (62.2)	14.4 (57.9)	14.2 (57.6)	15.4 (59.7)	17.2 (63)	18.3 (64.9)	19.7 (67.5)	21.4 (70.5)	18.58 (65.43)
Record low °C (°F)	16 (61)	17 (63)	16 (61)	11 (52)	8 (46)	4 (39)	1 (34)	7 (45)	9 (48)	12 (54)	11 (52)	15 (59)	1 (34)
Precipitation mm (inches)	171.1 (6.736)	130.5 (5.138)	105.6 (4.157)	56.5 (2.224)	31.9 (1.256)	17.6 (0.693)	19.6 (0.772)	15.0 (0.591)	44.4 (1.748)	54.7 (2.154)	81.7 (3.217)	85.0 (3.346)	813.6 (32.032)
Avg. precipitation days	8.1	7.6	7.0	4.4	2.8	2.4	1.8	2.2	3.2	5.5	7.9	7.5	60.4
% humidity	69.0	69.0	71.0	67.5	66.0	63.5	65.0	64.0	64.0	65.5	67.0	67.5	66.58
Mean monthly sunshine hours	248	226	248	240	248	240	248	248	248	217	210	217	2,838
Source #1: *World Meteorological Organization*[6]													
Source #2: *BBC Weather*[7]													

Appendix D

Raw data used to perform the flow analysis.

Total in system	2013 Novembro	2013 Dezembro	2014 Janeiro	2014 Fevereiro	2014 Março	2014 Abril	2014 Maio	2014 Junho	2014 Julho	2014 Agosto	2014 Setembro	2014 Outubro
m^3/day	31481	31138	27910	34267	30867	27066	30657	32600	30060	29678	32746	30661
L/s	364	360	323	397	357	313	355	377	348	343	379	355
m^3/day *0,8	25185	24910	22328	27414	24694	21653	24525	26080	24048	23743	26197	24529
L/s *0,8	291	288	258	317	286	251	284	302	278	275	303	284
Total in system two coming to the WWTP												
m^3/day	5223	5188	4802	5529	5075	4220	4852	5033	4752	4683	5269	4731
L/s	60	60	56	64	59	49	56	58	55	54	61	55
m^3/day *0,8	4178	4150	3842	4424	4060	3376	3881	4027	3802	3746	4215	3785
L/s *0,8	48	48	44	51	47	39	45	47	44	43	49	44
Total in system two if pumps work												
m^3/day	13251	13207	11707	14369	12824	10905	12695	13427	12722	12353	13727	12798
L/s	153	153	135	166	148	126	147	155	147	143	159	148
m^3/day *0,8	10601	10566	9366	11495	10259	8724	10156	10742	10178	9882	10982	10239
L/s *0,8	123	122	108	133	119	101	118	124	118	114	127	119
Discharging into bay												
m^3/day	26557	26233	23414	29071	26060	23145	26106	27872	25591	25299	27784	25948
L/s	307	304	271	336	302	268	302	323	296	293	322	300
m^3/day *0,8	21245	20986	18731	23257	20848	18516	20885	22298	20473	20239	22227	20758
L/s *0,8	246	243	217	269	241	214	242	258	237	234	257	240
Discharging into bay if pumps work												
m^3/day	18249	17948	16218	19917	18061	16175	17978	19190	17355	17342	19038	17881
L/s	211	208	188	231	209	187	208	222	201	201	220	207
m^3/day *0,8	14599	14358	12975	15934	14449	12940	14383	15352	13884	13873	15230	14304
L/s *0,8	169	166	150	184	167	150	166	178	161	161	176	166