Enabling the assessment of alternative water supply systems to promote urban water security in the Global South (AltWater)

Water supply and demand in Maputo, Mozambique:

Identification of plausible/likely alternative water supply solutions of water supply to Maputo

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Summary

Mozambique is a country vulnerable to extreme water-related events, with droughts and floods having the most negative impacts on the economy and the lives of the population. Most of the Mozambican population lives in rural areas and is dependent on subsistence agriculture, which is even more vulnerable to the shocks associated with climatic extremes, because it is generally dependent on rainfall. The National Institute of Meteorology (INAM) is the national institution responsible for the provision of climate information, and aware of this responsibility, particularly now with the threat posed by climate change, efforts have not been spared to bring to the public climate information that responds to the interests the public and in a simple way to understand

This climate information is not only an instrument for reducing vulnerability to climate variability and change in the country but is also an important factor for the development of water conservation forms for use not only during drought periods but as an alternative source to the use of treated water since it was already in the demonstration phase of demand for Maputo, it became evident that it cannot be satisfied by the traditional source.

Sources identified as being those that can be developed with some success.

The Maputo project team, after several and thorough surveys, was able to identify four important alternative sources of water to supplement existing supply sources, as follow;

•Rain water
• Floodwaters
• Reuse of sludge discharge washing water in the water treatment process in the Umbeluzi ETA
• Groundwater

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1. Rainwater resources

The Maputo Province, in the south of Mozambique, is one of the provinces experiencing prolonged drought. It is characterized by a season of low rainfall which can be relatively long. Seasonal rainfall shows a slightly negative trend at the provincial level. The early growing season is relatively precocious, leading to long growing seasons (up to 7 months in the south). Seasonal vegetation cover tends to increase moderately. The impact of the El Niño Southern Oscillation (ENSO) is relatively modest, with El Niño leading to lower average rainfall and vegetation cover and shorter growing seasons, while rainfall improves during La Niña seasons.

The inter-annual variation quantifies the seasonal rainfall varies from season to season. It is expressed as a map of the coefficient of variation of the annual rainfall of 1982 / 83-2016 / 17.

The annual rainfall variation is higher in the zones of lower seasonal rainfall, ie, drier zones are also more variable year after year, leaving these regions especially vulnerable to even small changes in water resources availability. This is evident in the more variable areas (provinces) that are: Inhambane, Maputo and Gaza (particularly the drier western zone). Inter-annual variation is a major climatic factor because it limits subsistence options: a large variation in rainfall contributes to the adoption of conservative, risk-averse strategies and a progressive shift towards non-agricultural livelihoods (from pastoralism, mining). Beyond a certain limit, agricultural livelihoods are no longer viable. It should be noted that the inter-annual variation includes two components: annual short-term random variations and longer term time trends. In Mozambique, the first component has preponderant dominance. The areas with the highest inter-annual variation correspond in large part to those with the highest risk of food insecurity.

1.1 Days of precipitation: monthly trends

When analyzing monthly trends, there is a tendency for fewer days of precipitation in the Northern provinces during most of the months, except in January. In the southern provinces (Maputo, Gaza, Inhambane), except for the increase in January, there is no definite trend in the number of days of precipitation.

The central provinces in December, and particularly in January, have a marked tendency to increase the days of precipitation. This reverses in February with a marked tendency to decrease the number of precipitation days, in particular in Zambézia with some continuation in March. There is good agreement with the rainfall trends as predicted, but negative trends in the number of precipitation days lead the duration or frequency of drought periods.

Table 1 Annual rainwater average precipitation

Localidade	Media/Ano	Jan	Fev.	Mar.	Apr.	Ma.	Jun.	Jul.	Ago.	Sept.	Oct.	Nov.	Dec
Namaacha Goba Fronteira	699.8	125.2	112	89.9	157	60	50	0	57.7	82.4	73.2	153	122
Boane ETA Umbeluzi	492.6	126.6	114	86.1	65.6	82.5	0	0	52	57.2	73.9	94.1	82.9
Maputo	860.0	186.9	161	79.8	80.7	91.4	0	147	0	133	70.3	128	69.8

Source: Meteorological Servive

Rainwater as an alternative source: How to take advantage of it?

1.2 Maputo Bridge Ka Tembe

As mentioned above, the average precipitation in the city of Maputo is 860 mm per year. Taking into consideration the recently inaugurated development of the suspension bridge that allows the crossing of the bay of Maputo to the municipal district of Katembe, there is a potential of utilization of waters resulting from rain onto this surface.

Figure 1 Maputo Ka Tembe Brdge. Source: aerial Image

The Maputo-Ka Tembe Bridge, which has a length of 3,000 meters and a width of 25 meters, covers an area of 75,000 m^2. Assuming 70% of the rainwater falling onto the surface will go to runoff, an annual volume of 45150 m^3 is the maximum volume potential. This water could in principle be reused for car washing in downtown Maputo and irrigation of green spaces (which is currently used for drinking water) and eventually for civil construction in the area of Ka Tembe which is a rapidly expanding area with serious difficulties in water supply[1]

The materialization of this project would consist of improving the existing rainwater channeling system for the storage of the water collected in buried reservoirs to be built on the two banks taking into account the architecture of the bridge (slope to the two banks).

[1] Source: Data from Maputo Municipality (infrastructure Department)

Figure 2 Drainage system currently on the bridge. Source: Joao Francisco photography

The implementation of the changes to take advantage of rainwater resulting from the drainage of the bridge depends greatly on the collaboration of the entity responsible for the management and maintenance of the bridge (Maputo South) taking into account that it is a recently inaugurated project (November 10, 2018). Therefore while there is large potential in this regard, realising a rainwater harvesting project here may not happen for some years.

1.3 Rainwater collection on buildings' roofs

Rainwater collected from buildings is also seen as a viable alternative water resource in Maputo. There is a great potential that is not exploited due to lack of knowledge, according to Law no. 16/91[2] of August 3 SECTION II. Uses resulting from the law, ARTICLE 23, (Uses established by law) nr 1, d) and numbers 2 and 3, this is to take advantage of the water fallen over all spaces granted for use and use of land including the roofs of houses. Therefore, there is policy to support rooftop rainwater harvesting in Maputo. On the other hand, it is necessary to establish a Municipal Regulation for city buildings which obliges the construction, among other parameters, of a rainwater retention law, obliging the construction of reservoirs for water collected by roofs and waterproofed areas, with the aim of not only to try to minimize the damages of the floods, delaying the launching of rainwater, but especially for later use. In order to do this, communities must be encouraged to install water troughs for individual tanks, which can be used in the bathrooms as well as for irrigation and car washing.

[2] Lei 16/91 de 3 de Agosto – lei de infraestruturas e ocupação de espaços-Moçambique

Figure 3: house with a rainwater collection system

Figure 4: house without a rainwater collection system. Source:Apene photography

The figure 4 illustrates a situation of fallen water from the gutters that for lack of collection device floods the yard and in the end the owner looks for ways to evacuate it without any use. From the point of view of the study group, conditions should be created for its use, by means of the construction of a cistern, and in periods of drought it may serve the purposes referred above.

2. Floods in Maputo: stormwater as a resource

Due to its location on the southeastern coast of Africa and downstream of several major rivers, Mozambique is considered to be extremely prone to recurring natural disasters, including floods, tropical storms, droughts and earthquakes. Nine of its rivers originate in neighboring countries, which requires good cross-border coordination for early warning alerts. Sixty percent of the population lives along the coast, and is therefore vulnerable to tropical storms (Report on recurrent flood recovery 2000-2013 Case Study for the Disaster Recovery Framework, 2014). According to research conducted recently by INGC, exposure to the risk of natural disasters in the country will increase significantly over the next 20 years and thereafter as a result of climate change. In general, it will be felt that the climate will be even more extreme, with periods of drought warmer and longer, and with more unpredictable rains; is expected to increase the proportion of intense tropical cyclones compared to the current situation (INGC, 2009). The previous report done by INGC(2009), Mozambique is

also expected to undergo changes in terms of water availability, and that by 2050 a large part of the country will experience greater pressure for lack of water.

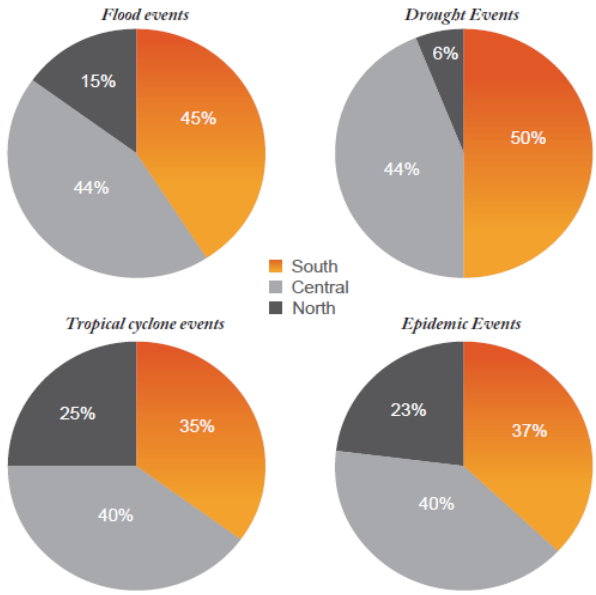

Figura 3. Desastres por região (período 1956-2008).
Fonte: Queface, 2009.

Figure 5 Disaster by period (1956-2008)

The analysis of the period between 1950 and 2008 shows that floods occurred on average every 2.8 years in the Maputo basin, every 2.6 years in the Umbeluzi. This implies that, on average, the rivers of Mozambique may exceed the level of flood alert every 2 to 3 years. Much less frequently large floods occur 1.5 times higher than flood alert level, approximately once every 15 to 20 years.

According to data from the National Statistical Institute (INE), Maputo is located in Maputo Bay, in Maputo Province, in southern Mozambique. The Bay forms the boundaries of the municipal zone in the South and East, the river Infulene limits the city to the West. The city is divided into a "cement city" with tall buildings, paved streets and developed infrastructures, and peri-urban areas with a very low level of residential infrastructure. It is structured in seven Municipal Districts that cover 64 neighborhoods with well defined limits. The KaMphumo Municipal District, known as the "city of cement", is the urbanized part of the city and extends on a plateau with an altitude between 44 and 60 m above sea level, covering an area of about 316 km^2.

Maputo is located in a tropical rainy zone, with two predominant seasons: hot and rainy between October and March and a cooler and drier season between April and September. The average temperature is about 19 ° C in the dry season and 26 ° C in the wet and hot season. The average annual maximum temperature is considered to be 31 ° C. So in the wet season, temperatures can exceed 40 ° C. The precipitation in Maputo is about 860 mm per year. Due to the tropical climate, the average air humidity varies between 75% in the cold period (June) and 81% in the hot period. (INE)

In urban areas where population density is most significant, environmental degradation can contribute to exacerbating the health and well-being of families. Endemic diseases such as malaria are a direct consequence of precarious drainage and sanitation that, in case of floods, can not drain the amount and flow of PARPA II water (2006-2009).

Figure 6: Flooded Cement City. Joao Francisco photography

Figure 7: Flooded peri-Urban areas. Joao Francisco & Apene Photography

For these populations, the occurrence of a precipitation, regardless of the level if it is high or low intensity, is a cause for concern, as backyards and streets are widened and water invades the homes.

Maputo is frequently effected by intense flooding, as often as once every year. In this period, Maputo, especially the outlying areas, will be covered with water, which carries considerable debris that, in addition to causing other impacts, obstructs the gutters and several other problems that derive from the deficit system of sewage.

An event on January 8, 2018 flooded 2210 homes and affected 8017 people in urban and peri-urban areas.

These and other problems are the justification for the water resulting from the floods to be partially captured, stored and reused, not only to minimize the suffering of the people but also for the reuse in view of the scarcity of water.

A viable solution to minimize flooding problems in particular in the urban area would be the construction of excavated reservoirs at strategic locations for storing water from heavy rainfall resulting in flooding. As the densely occupied cement city is the ideal place for the construction of these reservoirs, it would be in the green spaces of the city that would allow the use of this water for irrigation and other uses that are justified in particular the washing of vehicle.

Figure 8: Example of reservoir (can be prefabricated or built in situ)

In the figure below, a map of Google Earth shows the city's ground levels in yellow and demonstrates slope of the terrain. Most of the streets that have contributed to the floods, cross the Tunduro garden circled red in the map, which is a reason why good management of the drainage system would allow the collection of most of these waters at this point.

This location is therefore suggested because its location is not only strategic from a quota point of view, but it will also be easily restructured since it is a garden, allowing for not very significant costs to be made the combination of these two scenarios, that is, buried reservoirs to collect rainwater, avoiding floods in the downtown area, watering the garden and washing cars and reusing the upper part with the initial function of leisure space (garden). The natural gravity gradient reduces considerably the implementation of expensive infrastructure.

Figure 9: Map of the layout of the city and possible scheme of rainwater course and the proposed collection point

Streets whose drainage ditches drain into downtown Maputo City

Proposed location for rainwater harvesting - Jardim Tunduro

3. Water reuse

The water resulting from the filter washing process at waste water treatment plants represents the largest component in terms of waste water in the water treatment process and its uncontrolled disposal in watercourses such as the Umbeluzi ETA represents a danger to the environment. Therefore, it is intended to study the water characteristics resulting from the filter washing process in the Umbeluzi ETA for potential re-use in the network after due treatment

3.1 Contextualization

The Umbeluzi Water Treatment Plant is located in the province of Maputo, specifically in the Boane district of Mozambique, and is responsible for supplying three cities, the capital city of Maputo, Matola and Boane. It is the largest water treatment plant in the country and the largest population cluster it supplies is about 35 km away. It consists of three separate treatment lines, built in phases that are quite distant in time as a result of the increase in demand and have the same sequence of processes and unitary treatment operations namely: pre-oxidation, coagulation / flocculation, decantation, filtration, correction of pH (neutralization) and disinfection as shown in the figure below.

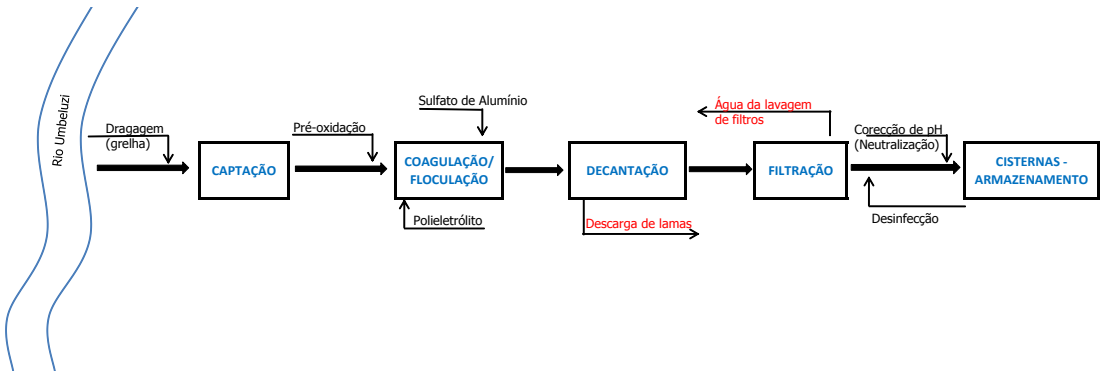

Figure 10: Linear treatment diagram

ETA has a total treatment capacity of 10,000 m^3 hr^{-1} (line 1 and 2, 3000 m^3 hr^{-1} each and line 3, 4000 m^3 hr^{-1}), water from the small Libombos dam (built on the Umbeluzi River) that is 10km from the catchment point.

The conventional treatment process at water treatment plants requires the use of potable water for filter washing, and the byproduct of this process is the water from filter washing whose final quality is not acceptable for direct reuse in the system, resulting in an effluent to be discarded or treated, and representing inefficient use of resources. To this effluent is added the muddy water discharged from the decanters, so the water treatment process generates waste.

In Mozambique, the coverage of the water supply service is 60%, and distribution is mostly intermittent, so water supply is still a major challenge, which is why water treatment plants are a priority compared to wastewater treatment. As a result, most Mozambican water treatment plants discharge their effluents (discharge of decanters and the filters water washing) into nearby watercourses without treatment, although environmental laws discourage this practice.

In recent years, despite growing environmental awareness as a result of the effort being made by environmental entities in audits, the practice is recurrent due to a lack of knowledge of the techniques used for treatment, compared to the current practice and the lack of permanent inspection by environmental entities. However damage to the environment is immeasurable ranging from the unpleasant visual aspect of the watercourse at the point of discharge, the increase in the concentration of toxic metals and suspended solids, (Di Bernardo and Dantas, 2005) to damage human health due to the occurrence of pathogens (Scalize, 1997).

In addition to the environmental issues that are related to the water quality of the receiving environment, it is necessary to consider the questions of quantity of water lost, this volume varies from 1 to 5% of the volume treated (Grandin, 1992), therefore its recovery may be of added value either for reuse in the system or for other purposes that do not lack potable water, thus reducing pressure on traditional sources. For example, the Umbeluzi Water Treatment Plant (ETA) serves 3 cities, Maputo, Matola and Boane, producing an average of 8,500 m^3 hr^{-1}, taking into account that the loss by filter washing and discharge of decanters is 3%, the volume of losses is 255 m^3 hr^{-1} or enough to supply about 50,000 inhabitants per day.

Figure 11: The filters washing water discharge. Joao Francisco photography

3.2 Reuse as an alternative

As Mozambique is a downstream country, it shares most of its hydrographic basins making the water resources situation unsafe and the water supply situation in some basins such as Umbeluzi is problematic. Therefore, the search for alternative solutions for the supply of water leads us to think of reuse solutions with the aim not only of protecting the environment but also responding to the present demand in the face of drought.

As the southern region of Africa is generally going through a period of drought, which continues in Mozambique for more than 3 years, the following disquietness arises, is not the filter-washing water an additional source of water for the supply? What are the constraints from a quality point of view for its reuse?

Taking into account the large volume of water lost, its effects on the environment, the safeguarding of legal aspects and in response to alternative solutions for the water supply in the context of drought, we intend to analyze the characteristics of the water of filters washing for re-use to the system.

Treatment and final disposal of ETA effluents - reuse

In general, because of the hydrological cycle, water courses (surface or underground) are the ultimate destination of any urban effluent. Due to this, care must be taken in the deposition of the effluents, essentially from the point of view of public health may be at risk if water is contaminated.

Mozambican decree no. 18/2004 of June 2, which defines environmental quality and effluent emission standards, considers as receiving means any environment where a pollutant can be discharged, river, lake, estuary, groundwater, ocean also soil and air. It establishes as the main foundation, not overcoming the ability to self-purify the environment or being overcome, the impact is not significantly negative for public health.

Although the maximum permissible parameters for each sector of activity are clearly defined, few comply with this directive because of three major factors: (i) lack of human, material and financial resources for effective supervision by the competent authorities; (ii) lack of infrastructure and (iii) poor quality control mechanism for industrial wastewater treatment for industries with individual treatment plants. This means that in Mozambique most of the wastewater is discharged into untreated waterways, with the concomitant risks involved.

4. Groundwater resources

The underground source for the Assignment Area managed by AdeM (cities of Maputo, Matola and Vila de Boane) is a practicable alternative solution, since, in addition to the main system that is the Umbeluzi Treatment Station (surface water), and it currently contributes to the demand for water in these cities.

By opening up the possibility of massive exploitation of Maputo aquifers, this solution / alternative could greatly relieve the pressure on surface waters, ensuring the supply through underground water to the suburban and / or expanding areas mainly to the north of Maputo, and surface water would be directed to the supply to the cities of Matola, Vila de Boane, because these two areas have high salinity indices. Another part of this surface water will be directed to the urban area of the city of Maputo.

4.1 Productivity of Aquifers of the Metropolitan Area

The analysis of the aquifer productivity chart in the metropolitan area of Maputo shows that the Northeast part of the district of Manhiça predominates very productive to productive aquifers. In the northern part of the district of Marracuene there is greater predominance of productive aquifers and a small part of aquifers very productive.

In the coastal strip of the districts of Marracuene, Manhica, Maputo Matola and a strip of Boane predominant moderate aquifers. In general, the latter shows that the entire coastal strip of the metropolitan area is predominated by very productive to moderate aquifers while Central and West is more predominated by agriculturists of limited productivity with a flow rate lower than 5 m^3 hr^{-1}. Figure 1.1 illustrates the spatial distribution of aquifer productivity.

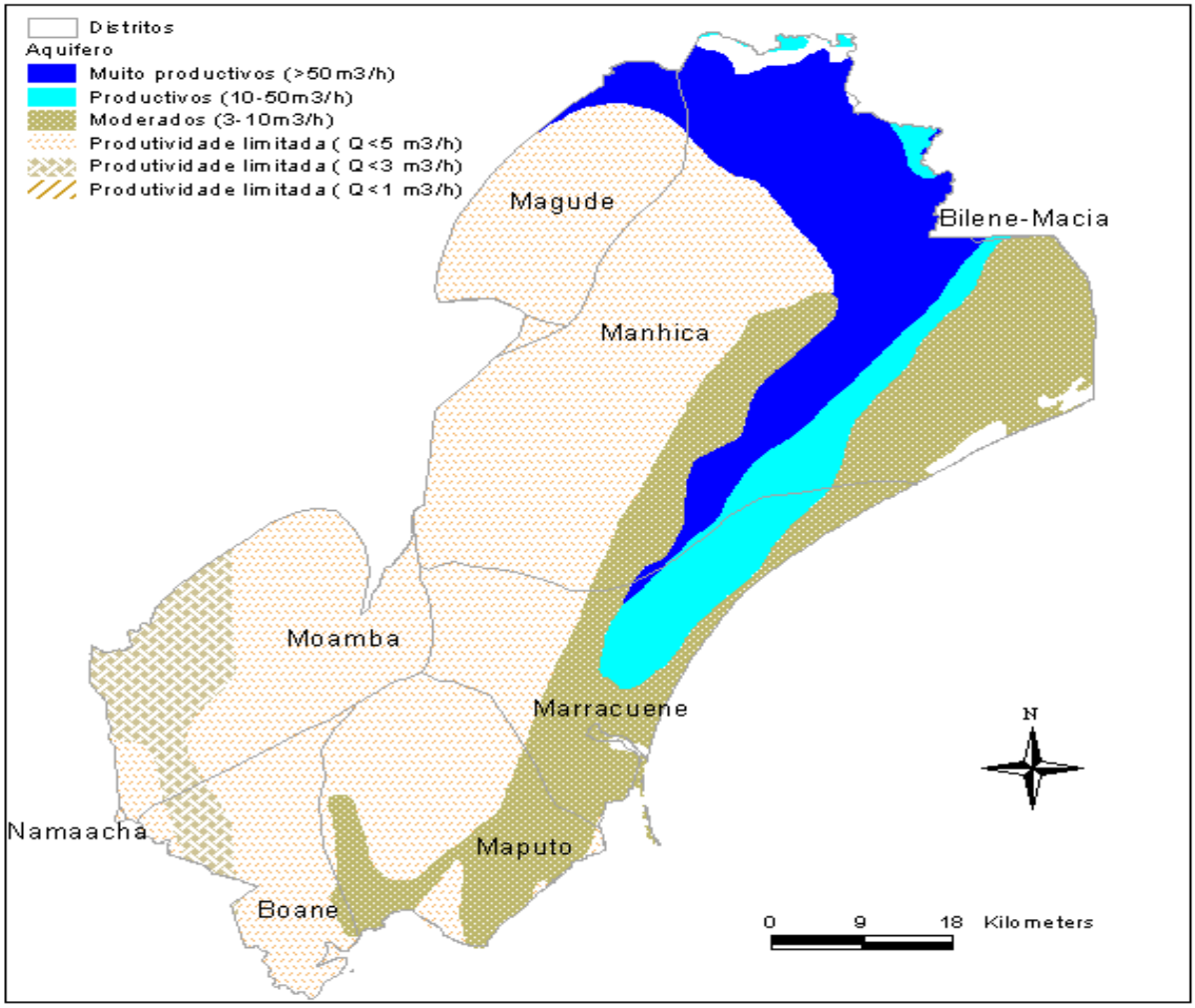

Figure 12: Illustration of spatial distribution of aquifer productivity

4.2 Productivity in the cities of Maputo and Matola

Regarding productivity in the cities of Maputo and Matola according to Figure 12 regarding the spatial distribution of aquifers productivity, it shows that almost all the neighborhoods of the coastal strip of the city of Maputo and some quarters of the city of Matola predominantly dominate aquifers moderately with flow rates ranging from 3 to 10 m^3 hr^{-1}.

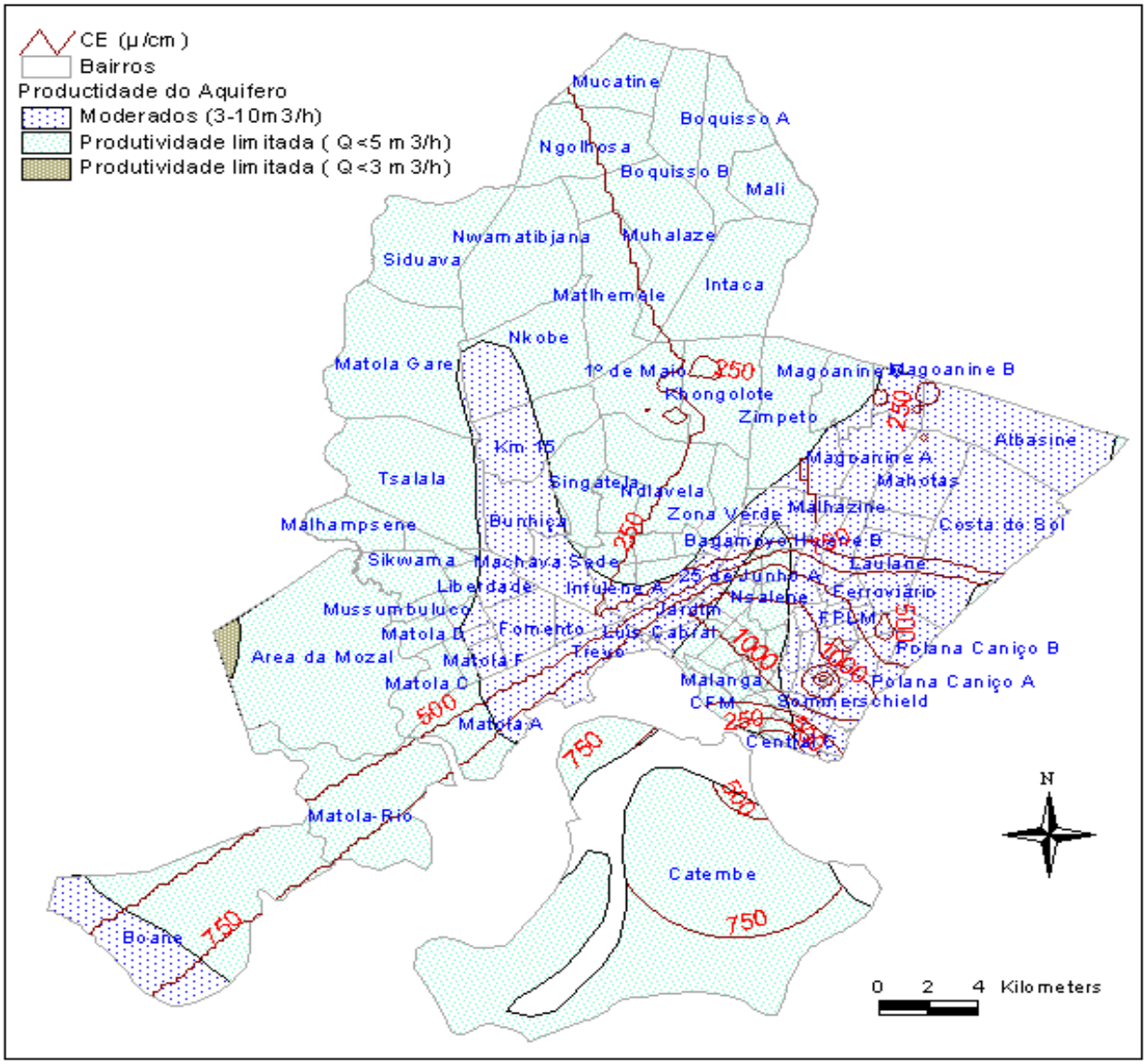

Figure 13: Spatial distribution of allied aquifer productivity at the level of salinity represented in terms of the isoline

As for the quality of the water, there is an aquifer of excellent quality with EC values ranging from 200 to 1500 µS cm^{-1}, except for a good part of the Municipality of Matola, Boane and the Administrative Post of Matola River.

It is pointed out that this is the only safe source for in case of prolongation of the dry season can supply the city of Maputo. But challenges are imposed in the system of its recharge due to the rapid growth of urbanization in the area.

As in the above description, it can be concluded that as groundwater in the Maputo Assignment Area, it can serve as an alternative source of great importance in the short and medium term, requiring the elaboration of an aquifer management plan, and fundraising of funds or investments for their realization

References

INGC. (2009). *Study on the impact of climate change on the risk of disasters in Mozambique - Summary Report.* National Institute of Disaster Management.

Management), I. (. (2009). *(Summary Report - Study on the impact of climate change on the risk of* disasters *in Mozambique.*

(2014,). *Report on recurrent flood recovery 2000-2013 Case Study for the Disaster Recovery Framework.* Maputo.

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