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DIAGNOSIS OF THE WATER SUPPLY SYSTEM: A CASE STUDY OF THE MUNICIPALITY OF MARABÁ-PA

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ABSTRACT
The Water Supply System (SAA) of Marabá-PA, established more than four decades ago, represents the main access to the vital water resource for many local residents. However, it faces significant challenges, such as frequent supply disruptions and rationing measures implemented by the responsible utility. This study aims to investigate the underlying causes of this scenario, identify possible weaknesses in the system and propose appropriate mitigating measures for each of them, with the aim of meeting the needs of the population. In the methodology adopted, official letters were sent and technical visits were made to the facilities of the Sanitation Company of Pará (COSANPA) to collect relevant qualitative and quantitative data. These data were processed using equations analogous to the Continuity Equation, and based on the results obtained, appropriate solution proposals were elaborated. The results revealed the presence of two distinct water supply systems in the city (Marabá Pioneira and Nova Marabá). The analysis showed deficiencies, especially in the collection and distribution network, as well as weaknesses in elevation and reservation. Each of these areas received specific proposals for improvement. In conclusion, it was found that the SAA of Marabá operates on two fronts: one characterized by robust and technologically advanced infrastructures in certain parts of the system, and another marked by fragility resulting from the lack of maintenance or investment in new technologies, the latter being the main responsible for the problems identified in this research.

Keywords: Water Supply. Weaknesses. Solutions.

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INTRODUCTION

According to Souza et al (2014), water is one of the most abundant elements in the Earth's crust, covering about 70% of the Earth's surface. It is an essential and indispensable element for the survival and quality of human life, given the intimate relationship of its activities with this natural resource

Water is one of the most important resources for the survival of living beings and for the conservation and maintenance of the environment and the relationships of dependence between living beings and natural environments. It is also necessary in the development of various economic activities such as energy generation, transportation and dilution of effluent (GARCIA; SWARTHY; FERNANDES, 2015; SUNTTI, 2016).

Given that water is an indispensable natural resource of a structuring and strategic nature for the socioeconomic development of a region, the supply of drinking water, in adequate quantity and quality and sufficient pressure, is one of the main priorities for the population (PEREIRA & TINÔCO, 2021).

Brazil is one of the countries with the highest availability of fresh water in the world, however it has a heterogeneous distribution within its national territory. The inequality in water distribution is also seen in the existing population difference between intensely anthropized areas and areas with low population density - such as rural areas (ANA, 2019).

Under these conditions, it is essential that its presence in the environment is in appropriate quantity and quality for its subsequent use (SOUZA, 2014).

Olivo (2014) points out that even with this proportion of water on the planet, there is still scarcity, especially due to the unequal distribution of this water resource.

On the other hand, ANA (2015) points out the municipality of Marabá as belonging to the Tocantins-Araguaia Hydrographic Basin, in an area corresponding to about 10.8% of the national territory.

Given this information, despite the geographical scarcity of water resources in several locations globally, it is possible to infer that in the municipality of Marabá, there is sufficient supply of water resources, however, there is a problem: Constant shortages and rationing in the water supply in the city. This situation causes several losses to the population, in addition to hurting their fundamental rights.

With this information, we proposed to investigate what is causing this situation and provide an answer about this issue that is recurrent in the municipality. Once completed, it

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will be following the order of Federal Law No. 9433 of 1997 (BRASIL, 1997), which has as one of its objectives to ensure the necessary availability of water to current and future generations, in quality standards appropriate to the respective uses.

In addition to the legal obligation, the objectives fulfilled in this work provided knowledge for the development of tools necessary for the correction of these failures, improving the efficiency and effectiveness of the Water Supply System in Marabá-PA, being a work of socio-environmental relevance, since, for Chagas (2023), the SAA play a crucial role in promoting the health of the population in urban and rural areas, reducing the occurrence of waterborne diseases, and for this, it is necessary for it to function properly.

OBJECTIVES

GENERAL

To evaluate the operational capacity of the water supply system in the municipality of Marabá, PA.

SPECIFIC

- Identify the data for diagnosis of the water supply system of the municipality of Marabá - PA;
- Check the points of weakness of the water supply system;
- Propose mitigating measures for the cadres that fail.

LITERATURE REVIEW

LEGAL ASPECTS

With regard to the legal criteria in terms of basic sanitation for the population, more specifically in water supply, the following stand out:

The Brazilian Magna Carta of 1988 (BRASIL, 1988), which employs, in its Article 23, Item IX, the competence of the Union, States and Municipalities in the creation of programs to improve basic sanitation.

The National Environmental Policy, instituted by Law 6.938 of 1981 (BRASIL, 1981), in its Article 2, item II, points to the rationalization of the use of soil, subsoil, water and air as one of the principles of this Law.

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Another aspect to be considered is Law 9.433 of 1997, which institutes the National Water Resources Policy (PNRH), (BRASIL, 1997), in its Article 1, item VI, which deals with the responsibility in the management of water resources, indicating the Government as one of the agents in this matter.

There is also Federal Law No. 11,445 of 2007 (BRASIL, 2007), which considers, in its Article 2, item III, water supply as one of the fundamental principles of public basic sanitation services.

Another relevant issue is found in the PNRH (BRASIL, 1997), Art 1, Items I and II, which point to water as a good of public domain and limited natural resource, emphasizing the need to avoid any losses to this environmental good.

Finally, Municipal Law No. 16,885 of 2002 (MARABÁ, 2002), which institutionalizes the Municipal Environmental Policy, points out in its Article 3, item VIII the objective of ensuring the use of natural resources in an ecologically balanced way, aiming at the eradication of poverty and the reduction of social inequalities.

Therefore, the observance of these legal aspects guarantees the population the right to receive water in their homes in a quality and quantity satisfactory to the demands of each address.

CONTINUITY EQUATION

Netto (2015) points to the continuity equation as an expression of the law of conservation of masses. This equation expresses that the inlet flow is always equal to the outflow rate. This knowledge is relevant because, if there is a discrepancy between these flows, it means that some loss is occurring along the way, making it useful in identifying losses in the elements that make up the SAA. It can be written according to equation 1:

$$A_1.V_1 = A_2.V_2 \qquad (1)$$

Of which:

A = Area

V = Speed

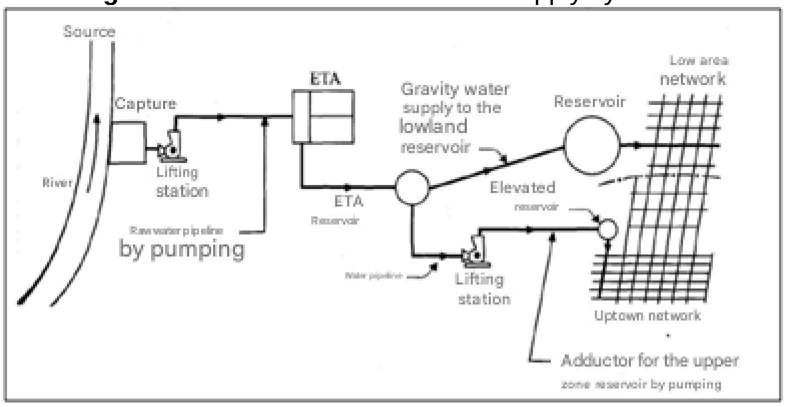
WATER SUPPLY SYSTEM

Gomes (2001) states that water supply systems comprise the set of works and equipment intended to meet the needs of domestic, public and industrial consumption of a community. These systems must provide water, in quality and quantity, indiscriminately to populations with the lowest possible expenditure.

The author also points out that water supply systems can be divided into six distinct parts: spring, collection, adduction, treatment, reservation and distribution network, with an increase in any of the stages, as long as necessary. Distribution networks are the components responsible for bringing water to the end user in the water supply systems of urban and rural communities. There is still a sixth part that must be considered, because it is the beginning of everything: the springs.

Heller (2010) separates the components into three major groups: Production Units, Distribution Units and Transport Units. The production units include the units upstream of the first reservoir of the system, starting with the abstraction, passing through the adduction of raw water, treatment and adduction of treated water. The distribution units include the reservoirs and the distribution network. The transport units correspond to the set composed of the pumping stations and the corresponding pipelines. Figure 1 presents a general scheme of an AAS

Figure 1: General model of a water supply system



Source: Silva (2016)

Springs

Heller (2010) states that springs are the sources of water, from which the system is supplied. In general terms, the springs can be of the type: Phreatic or unconfined underground, confined underground, surface without accumulation, surface with accumulation and rainwater.

Netto (2015) states that there are two main types of water sources in water collection: surface and groundwater.

According to the author, surface springs are artificially created streams, rivers, lakes and reservoirs, and the latter, when built with the purpose of guaranteeing a certain volume of water for public supply purposes, become part of the system's catchment.

The author also points out that underground springs are the sources of outcropping water, or groundwater and confined aquifers. In order to choose each of them, studies on the local geology and hydrology are necessary in order to determine the available flows in each situation.

Abstraction

According to Heller (2010), the catchment stage consists of the structure responsible for extracting water from the spring, in order to make it available for transport to the places of use. It can be in many different ways, depending on the type of source. Its design, especially when it refers to the withdrawal from a surface source, must carefully consider the physical characteristics of the watercourse and its banks, as well as the seasonal variations in flow, since it is a unit of great responsibility in the system and, because it is located in the watercourse, it is subject to the action of the weather.

For the development of projects for catchment systems in surface springs, Netto (2015) highlights the following items:

Hydrological data of the basin under study and, in the absence of these data referring to nearby and/or similar basins for correlation studies between them, notably with regard to the specific flow of the basin;

Fluviometric data of the watercourse to be used and, failing that, elements that relate to the oscillations of the water level in periods of drought and floods, as well as on the occasion of torrential rains. Such information may be collected from people who know the region, residents of the vicinity, and corroborated by typical marks on the margins;

Elements referring to the physical, chemical and microbiological characteristics of the water to be used, with special emphasis on the determination of any polluting and/or contaminant sources existing upstream of the chosen catchment site. Water samples must be collected to be collected for laboratory tests.

Regarding groundwater abstraction, Netto (2015) states that the diameter of the wells varies as a function of the aquifer's water supply capacity and the opening and construction process. Normally the minimum diameter is 1 m, for constructive reasons. In cases of layers that can only supply water very slowly, they can reach 8 to 10 m in

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diameter. As for the depth, they are usually less than 30 m, and the penetration into the aquifer layer does not exceed about 7 m, depending on the geological formation of the aquifer layer and the position of the sheet to be used. As the diameter and/or penetration into the aquifer layer (and the depth of the liquid layer) increases, the stored volume increases. From the well, the water can be pumped to the treatment site and subsequent distribution.

Pump power

The power of the pump, according to Netto (2015) is given by equation 2:

$$P = \frac{\gamma \text{ x } Q \text{ x } Hman}{75 \text{ x } \sigma global} \qquad (2)$$

Of which:

P = Power (CV)

γ = Specific weight of the fluid (kgf/m³)

Q = Flow rate (m³/s)

Hman = Headroom (m.c.a)

75 = Constant value of the equation

σglobal = Yield of the motor-pump assembly, given by means of equation 3

$$\sigma global = \sigma motor \text{ x } \sigma bomba \qquad (3)$$

Of which:

σ_{global} = Efficiency of the motor-pump assembly

σ_{motor} = Engine performance

σ_{bomba} = Pump Yield

Adduction

Heller (2010) says that adduction is the phase that is intended to transport water, interconnecting collection units, treatment, pumping stations, reservation and distribution network. Depending on the water it transports, it can be a raw water or treated water pipeline and, depending on its hydraulic characteristics, it can be in a free conduit, in a conduit forced by gravity or in settlement. It is a phase that is present in all the others of the SAA.

Still in terms of adduction, Heller (2010) highlights the Pumping Stations. These may prove necessary when the water needs to reach higher levels, overcoming geometric unevenness. There are systems without pumping stations, in the same way that there are others with dozens (sometimes hundreds) of them. Its use is mainly due to the local relief. They can be classified according to the water they repress (raw or treated) and the type of pump.

The main pipes intended to transport water between the units of a supply system that precede the distribution network are called pipelines. They connect the water collection and intake to the water treatment plant, and the latter to the reservoirs of the same system. In the event that there are derivations of a pipeline intended to conduct water to other points in the system, constituting secondary pipes, these will be called sub-pipelines. Pipes that carry water from one distribution reservoir to another are also called subpipelines (NETTO, 2015).

Treatment

The treatment, which is always necessary to make the quality of raw water compatible with potability standards and protect the health of the consuming population, according to Ordinance MS No. 518/2004 (BRASIL, 2004). This Ordinance establishes the following minimum conditions for treatment: All water supplied collectively must be subjected to a disinfection process; being supplied by surface source and distributed through channeling, it must include treatment by filtration (HELLER, 2010).

According to Netto (2015), water treatment is done to meet several purposes, namely: Hygienic purposes: removal/reduction of microorganisms (bacteria, cysts, viruses, algae, protozoa, etc.), toxic or harmful substances, dissolved or in suspension, high levels of organic and inorganic compounds, impurities hygienically objectionable or limited by law; Aesthetic purposes: removal/correction of color, turbidity, odor, flavor; Economic purposes: removal/reduction of corrosiveness, fouling (hardness and others), color, turbidity, iron, manganese, odor and flavor.

There are, according to the author, seven processes in water treatment, namely: Microsieving, Aeration, Coagulation and Flocculation, Decantation/sedimentation, Filtration,

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Disinfection, and Contact Treatment. Each technology is variable according to the parameters of the water source.

Microsieving

For retention of fine non-colloidal suspended solids, e.g. algae. Usual minimum aperture (economically): 0.1 mm.

Aeration

An aeration unit is required for: removal of excess dissolved gases in the waters (C02, H2S); removal of volatile substances; introduction of oxygen (including for the oxidation of soluble iron, manganese and others).

Coagulation and Flocculation

Coagulation is a chemical process that aims to agglomerate impurities that are found in "suspensions, called fine", in a colloidal state, into "larger particles, called flakes", which can be removed by sedimentation and/or filtration. The particles aggregate, forming inconsistent gelatinous formations, called flocs. The initial flakes are formed quickly and the other particles adhere to them.

Decantation/Sedimentation

They represent the operation of separating solid particles suspended in water (usually done dynamically). These particles, being heavier than water, tend to precipitate, and then the phenomena called decantation and sedimentation occur. The water, free of particles that settle, is removed by devices installed at the opposite end of the inlet.

Filtration

Filters are the "heart" of ETAs. In fact, it can be said that the other units serve to help the filters in their task of retaining impurities and working longer without the need to be washed.

Disinfection

The disinfection of water for supply purposes is a measure that, on a corrective or preventive basis (when it has a residual effect), must be adopted in all systems. Only a well-controlled disinfection process, before the water reaches the point of consumption, can guarantee the quality of the water, from the point of view of public health.

Contact Handling

Contact treatment consists of promoting the contact of water with a predetermined material in order to retain undesirable substances present in the water.

Reservation

Regarding the reserve, Heller (2010) states that they are intended, among other functions, to compensate between the production flow, from the capture-adduction-treatment, which in general is fixed or has few variations, and the consumption flows, which vary throughout the hours of the day and throughout the days of the year. They can take different forms, depending on their position on the ground (supported, elevated, semi-buried, buried) and their position in relation to the distribution network (upstream or downstream).

Netto (2015) says that distribution reservoirs can meet the following conditions:

- Function as lungs (compensation, "flywheels") of distribution, taking into account the hourly variation of consumption (useful volume);
- Provide a water reserve for consumption peaks during firefighting;
- Maintain a reserve to meet emergency conditions (accidents, repairs to facilities, adduction interruptions and others);
- Allow pumping manoeuvres during high electricity tariff hours (if shown to be cost-effective).

For the author, to satisfy the first condition, the reservoirs, empirically, must have a capacity greater than 1/8 to 1/6 of the volume consumed in 24 hours.

Also according to Netto, 2015, to meet the second condition, it will be necessary to consider a portion that is only operable in these situations, that is, the operational water output is above the bottom and the fire output, at the bottom, requiring operation by the firefighters.

The third condition, "emergency plot", will depend a lot on local conditions and the engineer's discretion.

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Finally, according to the author, for the fourth condition, it is important to work carefully on it, showing that the initial investment will be compensated, or not, by the energy savings at peak hours and that one thing is not being exchanged for another, because what could be adduced and/or pumped in 24 hours may now have to be done in 20 hours. increasing diameters, etc. It is possible that the intelligent operation of the reservoir "gaps", especially before reaching the last year of the project horizon, will allow for interesting savings, without changing the volume.

Distribution network

Finally, in terms of the distribution network, Heller (2010) describes the Distribution Network as the part composed of pipes, connections and special parts, located in public places, and its function is to distribute water to homes, commercial establishments, industries and public places. It can assume very simple to extremely complex configurations, depending on the size, demographic density, distribution and topography of the area supplied.

Netto (2015) says that the network is the unit of the system that conducts water to the points of consumption (homes, industries, etc.) in an appropriate way, in the desired quantities, under the established pressures and preserving the quality of the liquid. It consists of a set of pipes, connections and special accessory parts, which usually follows the layout of streets and sidewalks forming a "network" equal to that of the street network of a city.

The author also explains that the SAA must be "sectorized" in such a way that macro-measurement sectors can be created to compare with the sum of micro-measurement in the sector and keep the "losses" under control.

Conditions for the proper functioning of the water supply system

Netto (2015) determined 11 conditions to help ensure the proper functioning of the SAA, namely:

The first is that the system should be "sectorized" in such a way that macro-metering sectors can be created to compare with the sum of micro-metering in the sector and keep the "losses" under control.

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Water distribution systems must be designed and built to work, at all times (continuously), with adequate pressure at any point in the network. Regulatory frameworks must establish, statistically, the interruptions allowed to cover accidents, maintenance, etc.

In the second it is said that leaks (physical losses) in the pipes should be limited to normally accepted values (it is impossible to obtain 100% tightness in a network buried with different materials, connections, ages, etc.). Normally this number should be below 10%, but it is very difficult to separate what is network leakage and connections (household connections before water meters) from what is unmetered water (for example, errors for less water meters).

For the third, the system should be "sectorized" in such a way that macro-metering sectors can be created to compare with the sum of micro-metering in the sector and keep the "losses" under control.

The fourth imposes that the system must include valves and flushing devices at all convenient points to enable repairs and discharges, whenever necessary, sectorizing and minimizing interruptions or non-conformities in the supply.

The fifth decides that qualitative water safety must be maintained throughout the network, at all times, within the allowed parameters (limits).

In the sixth it is said that the system must be protected against external pollution, the reservoirs for water already considered potable must be covered and fully protected.

The seventh clause provides that any possibility of introducing water of inferior quality into the network must be avoided. Drinking water pipes must avoid becoming immersed in polluted liquids (groundwater, crossing canals, etc.).

In the eighth, the network must be planned to ensure good water circulation, tolerating a minimum number of ends without circulation.

Considering the ninth, the network must be maintained in sanitary conditions, avoiding all possibilities of contamination during the execution of repairs, replacements, relocations and extensions.

On the tenth, when laying new pipes and repairs to existing lines, the pipes must be disinfected with a concentrated chlorine solution (50 mg of chlorine/liter of water) for 24 hours. After this period, this solution is discharged, filling the pipes with clean water. This operation can and should be controlled by microbiological analyses.

And finally, for the eleventh, whenever possible, drinking water pipes should be laid in ditches located more than 3 m from the sewers. At intersections, the vertical distance

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must not be less than 1.80 m. When it is not possible to maintain this separation, special care is recommended to protect the water pipe from contamination by sewage. These precautions may include lining the sewer pipes or using ductile iron pipes.

MATERIALS AND METHODS

The present work was developed as a Case Study, which according to Ventura (2007), originates in medical research and psychological research, with a detailed analysis of an individual case that explains the dynamics and pathology of a given disease. With this procedure it is assumed that knowledge of the studied phenomenon can be acquired from the intense exploration of a single case. Applied to Engineering, this methodology is seen as the analysis of an existing problem to obtain a diagnosis.

This study is classified as exploratory, presenting qualitative-quantitative analyses, since it proposed to seek the reason for the existing problem in Marabá through calculations, and also to propose the appropriate solutions based on the results found.

Rangel, Rodrigues and Mocarzel (2018) highlight that the quantitative approach is the one that makes it possible to carry out analysis of research data, seeking to measure and dimension them for what is intended to be observed, not only their foundations and characteristics, but also some aspects that can be references for comparisons with qualitative research, also observing, from a perspective of complementarity, the qualiquantitative option

Martelli, et al (2020) point out that exploratory research can also be defined as a study that aims to know the study variable as it is presented, its meaning, and the context in which it is inserted.

FIELD OF STUDY

According to IBGE (2022), the municipality of Marabá has about 266 thousand inhabitants, with an area of approximately 15,128 km, located in the southeast of the State of Pará, with the Latitudinal coordinates -5.36997 and Longitudinal -49.1169, with access through BR 230 (Trans-Amazonian Highway). Figure 2 shows the location map of the urban area, where the SAA is installed. There is no information on the network map.

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Figure 2: Location map of the city of Marabá

Source: Authors, 2024

DATA COLLECTION

At this stage, data from External Letter No. 004/2023 (COSANPA, 2023), from the General Coordination of COSANPA UN-TO, of October 20, 2023, were taken.

The letter was prepared by the authors of this work, and requested all the information regarding the SAA of Marabá-PA so that, through them, the necessary calculations could be carried out to fulfill the other specific objectives of this work.

The data requested were: Description of the structure of the WTP, Treatment capacity of the Stations, Withdrawal flows, Flows effectively produced by the WTPs, Outlet flow of the WTP pumps, Capacity of the supported reservoirs, Capacity of the elevated reservoirs, Flow of the pumps for each elevated reservoir and what is the daily period pumped to each sector.

DETECTION OF WEAKNESSES

In the detection of weaknesses, calculations were performed using the numbers obtained through data collection, taking into account the following aspects:

Efficiency of the collection system

To determine whether the withdrawal flow is sufficient, the principle of continuity adapted to equation 4 was used:

$$Qc \geq Qeta \qquad (4)$$

Of which:

Qc = Flow distributed by the withdrawal

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$Qeta$ = Total flow rate of the WTP

The use of this equation is justified by the argument that, through it, it is possible to determine whether the catchment has sufficient flow to supply the WTP or not. If these conditions are not met, it is possible to say that the withdrawal flow is insufficient.

Capacity to process ETAs

To determine whether the treatment plants have the treatment capacity to supply the abstraction, the equation 5 was also adapted from the principle of continuity:

$$Qeta \leq Qp \tag{5}$$

Of which:

$Qeta$ = total capacity of the WTP

Qp = Flow produced

If the statement in equation 5 is true, it is possible to infer that the WTP is working at its full capacity. Otherwise, the issue that prevents it from being real must be investigated and resolved.

Lifting efficiency

To define whether the elevation flow is sufficient, the equation used is analogous to that of the withdrawal flow. Equation 6.

$$Qe \geq Qeta \tag{6}$$

Of which:

Qe = Lifting flow rate

$Qeta$ = Flow produced by the WTP

If the requirements of this equation are met, the efficiency of the pumping stations after treatment can be determined. Being a fundamental aspect to give flow to the treated water at the Station.

Capacity of supported reservoirs

To determine whether the supported reservoirs are fulfilling their function of keeping the flow rate stable in the distribution of the supply system, equation 7 was used:

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$$Cap \geq 1/6Qe \qquad (7)$$

Of which:

Cap = Reservoir capacity

Qe = Flow at the inlet of the reservoir in one hour

To determine whether these are capable of functioning as emergency reserves, equation 8 was adopted:

$$Cap \geq 2Qe \qquad (8)$$

Of which:

Cap = Reservoir capacity

Qe = Flow at the inlet of the reservoir in one hour

The constant "2" was applied in this equation as an arbitrary value, which Netto (2015) states can be used in the emergency reserve situation

Capacity of elevated reservoirs

Similarly to the calculation of supported reservoirs, to determine whether the elevated reservoirs have sufficient capacity to act as lungs, equation 9 was used:

$$Cap \geq 1/6Qe \qquad (9)$$

Of which:

Cap = Reservoir capacity

Qe = Instantaneous reservoir inlet flow in one hour

To determine whether these are capable of functioning as emergency reserves, equation 10 was adopted:

$$Cap \geq 2Qe \qquad (10)$$

Of which:

Cap = Reservoir capacity

Qe = Instantaneous reservoir inlet flow in one hour

For the elevated reservoirs, the same criteria and justifications were used for the supported reservoirs.

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Efficiency of the distribution network

To determine whether the network is capable of discharging all the treated water that arrives at the reservoirs, qualitative parameters were adopted, such as the efficiency of the micromeasurement, accuracy of the detection of the level of the reservoirs and, if there are none of these, the company's consumption estimates, since quantitative data were not obtained for this stage of the SAA.

CORRECTION OF WEAKNESSES

After evaluating the main aspects, a proposed solution for each possible problem was considered according to the indicators evaluated:

Efficiency of the Pickup and Lift System

If catchment problems occur, the first possible solution is to increase the pumping power, which according to Netto (2015), must respect the fluid used (water), head of head, pump efficiency, design flow and a constant equal to 75.

As a second option, there is also the solution that consists of connecting more than one pump simultaneously, if there is one, but this requires a prior study of the conditions of the source and the facilities in which the equipment is located: The main requirement that must be evaluated here is whether the pumps will receive the minimum positive suction load (NPSH) necessary so that cavitation does not occur.

Capacity to process ETAs

If there is a problem in the Treatment Plants, the solution is to check for possible malfunctioning devices or damaged structures during the process and, if there is not, the installation project of an expansion or a new Station must be carried out considering current and future demands.

Capacity of supported and raised reservoirs

Whenever the reserve is insufficient for any of its purposes, it is necessary to build new reservoirs in order to expand its capacity.

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Efficiency of the distribution network

As this topic worked with qualitative data, if there is a problem here, the solution is also qualitative, of implementing or improving materials and methods of micromeasurement, reservoir level and consumption estimation according to need.

Micrometering data is essential for the concessionaire to keep losses under control, according to Netto (2015), but this technology also allows knowledge of the demand of each consumer individually, without consumption estimates.

The instantaneous knowledge of the level of the reservoirs corroborates items one, three and eight of Netto (2015) and in practice is able to provide instantaneous data on consumption and demand of the addresses, in addition to allowing statistical data to be collected for the development of research.

Consumption estimation is essential, especially in case of absence of the two topics previously discussed, because through it, even without such precision, it is possible to estimate the demands and resize the points of greatest fragility according to the values found.

PROBLEM X SOLUTION RELATIONSHIP

Table 1 presents a matrix of the problem-solution relationship considering all the problems that can be found through the equations presented in item 4.3 of this work and all their possible solutions.

Table 1: Matrix of the Problem x Solution relationship for Marabá-PA

Problem	Solution
Insufficient withdrawal	Acquisition of new pumps
	Simultaneous connection of pumps
Insufficient treatment	Facility expansion
	Construction of new WTPs
Insufficient elevation	Acquisition of new pumps
	Simultaneous connection of pumps
Low reservoir capacity	Build more reservoirs
Insufficient or no micro-metering	Implement efficient technologies
Failure to measure the level of the reservoirs	Implementation of efficient technologies
Failed or missing consumption estimation	Preparation of technical-scientific works that deepen this issue

Source: Authors, 2023

It is worth mentioning that for each of the problems that have multiple solutions, the context must be taken into account: The simultaneous connection of pumps will only be

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possible if there is extra equipment, otherwise, it will be necessary to purchase new ones and the construction of new WTPs will only be necessary if it is not possible to expand them either due to lack of space or logistics.

RESULTS

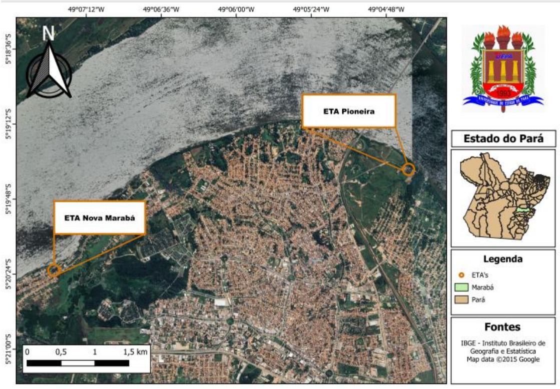
DATA COLLECTION

At this stage, data from External Letter No. 004/2023 (COSANPA, 2023), from the General Coordination of COSANPA UN-TO, of October 20, 2023, were taken.

Structure of the SAA

The Marabá Water Supply System is divided into two, with two Water Treatment Plants (WTP) located in the Nova Marabá and Marabá Pioneira nuclei, as shown in figure 3.

Figure 3: Location of the Marabá WTPs



Source: Authors, 2024

SAA Marabá Pioneira

The Marabá Pioneira WTP System has its own catchment, with water being captured, treated, stored in a supported reservoir and distributed directly to the population through a pumping station. This Station provides water resources only for the nucleus where it is installed.

Funding

The raw water collection for this system is carried out in a surface source (Tocantins River) and uses a surface pump, as shown in figure 4.

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Figure 4: Catchment raft

Source: COSANPA, 2023

Compact WTP

The treatment of the WTP is divided into two parts, one of which is a compact station, and the other with the elements of a conventional WTP. Figure 5 shows the structures of the Compact WTP.

Figure 5: Compact WTP

Source: COSANPA, 2023

Chemistry House

The WTP also has a small facility, as shown in figure 6, intended to deposit and apply chemicals for water treatment, especially chlorine (Cl) for disinfection of the water resource and other coagulant solutions for the decantation process.

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Figure 6: Chemistry house

Source: COSANPA, 2023

Russian Filter

After the process of coagulation, flocculation, usually assisted by chemicals, the water passes through filters, such as those in figure 7, to retain all impurities that are not tolerable to finally go through the chlorination process and be distributed.

Figure 7: Russian filter

Source: COSANPA, 2023

Pump House

The Station also has a small pump house that acts as a Pumping Station, according to figure 8. This structure contains the pumps that flow the water to the supported reservoir of the System.

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Figure 8: Pump house

Source: COSANPA, 2023

Supported Reservoir

The supported reservoir shown in figure 9 receives the treated water from the Station, stores it and distributes it with the help of pumps to the population. In this System there are no elevated reservoirs, and the water resource is pumped directly to people's homes.

Figure 9: Supported reservoir

Source: COSANPA, 2023

SAA Nova Marabá

The Nova Marabá WTP system is more complex: Also counting on collection in the Station's own facilities, the water is captured by surface pumps and a collection well, treated and pumped in the WTP to two supported reservoirs located at another address, but in the same nucleus, where the water resource is stored and distributed via pumping

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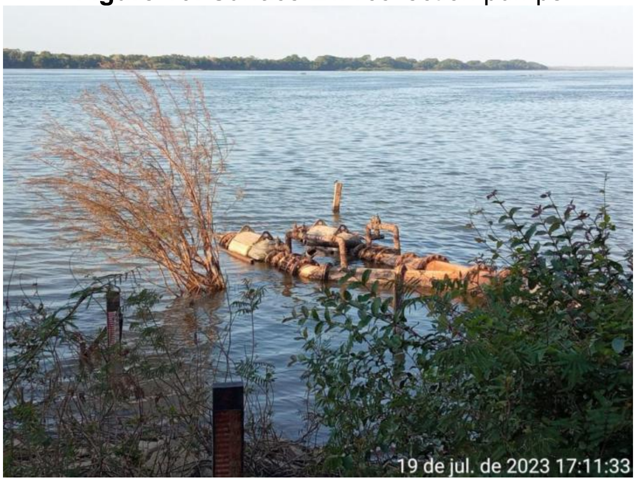
to all elevated reservoirs in the sectors where COSANPA serves in the municipality of Marabá. Once at this stage, gravity supply to addresses occurs.

Abstraction

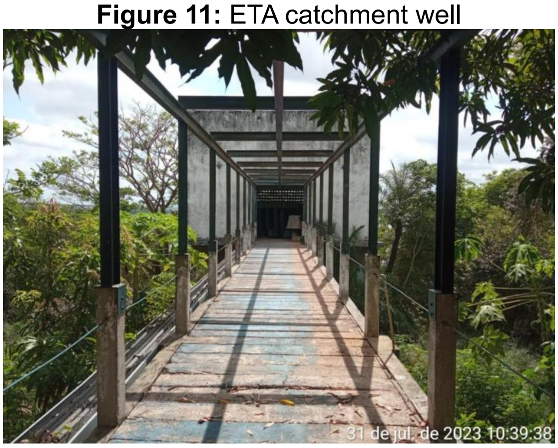
In the Nova Marabá System, there is also withdrawal from a surface source (Tocantins River) and with surface pumps, according to figure 10. But this system still has a 600mm diameter surface well for removing raw water from the river, as shown in figure 11.

Figure 10: Surface ETA collection pumps



Source: COSANPA, 2023

Figure 11: ETA catchment well



Source: COSANPA, 2023

Chemistry House

Like the other WTP, Nova Marabá has a structure, shown in figure 12, intended for the storage and application of treatment chemicals, especially Chlorine (Cl) and other flocculant substances for the decantation process

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Figure 12: Chemical house ETA

Source: COSANPA, 2023

Decanters and Filters

This Station has decanters, as shown in figure 13, whose function is to retain the suspended solids coagulated at the bottom of its reservoirs to reduce the obstruction of the filters shown in figure 14.

Figure 13: ETA decanters

Source: COSANPA, 2023

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Figure 14: ETA Filters

Source: COSANPA, 2023

WTP Pumping Station

The WTP has an internal Pumping Station, as shown in figure 15, which has the function of pumping the treated water to another Pumping Station that holds the reservoirs supported for water storage, the elevated reservoirs for distribution in the Nova Marabá nucleus and will pump the water to the other elevated reservoirs.

Figure 15: ETA Pumping Station

Source: COSANPA, 2023

Supported reservoirs

In the Pumping Station, there are two supported reservoirs, shown in figures 16 and 17, which hold all the water produced in the WTP, and will flow, with the help of pumps, to all the elevated reservoirs in which the SAA Nova Marabá distributes.

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Figure 16: 1st Reservoir supported by Pumping Station

Source: COSANPA, 2023

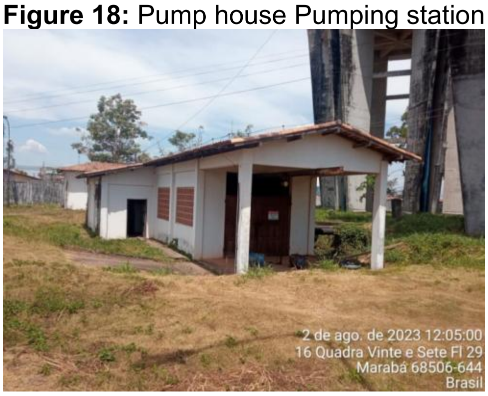
Figure 17: 2nd Reservoir supported by Pumping Station

Source: COSANPA, 2023

Pump House

The Pumping Station has a pump house with 5 pumps: Two working for the Nova Marabá sector and three working for the Cidade Nova and Laranjeiras sectors. Figure 18.

Figure 18: Pump house Pumping station



Source: COSANPA, 2023

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Nova Marabá elevated reservoirs

The Pumping Station also has a pair of elevated reservoirs that distribute water to the sector in which it is located (Nova Marabá). Figure 19.

Figure 19: Elevated reservoirs Pumping Station

Source: COSANPA, 2023

Cidade Nova elevated reservoir

In the elevated reservoir of Cidade Nova, there is a small pumping station to assist in the distribution to the addresses of this nucleus. Figure 20.

Figure 20: Cidade Nova elevated reservoir

Source: COSANPA, 2023

Laranjeiras elevated reservoir

In the Laranjeiras neighborhood there is also an elevated reservoir that has the same function as the others: Distribute water to end consumers. Figure 21.

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Figure 21: Laranjeiras elevated reservoir

Source: COSANPA, 2023

The treatment capacity of the plants

- Nova Marabá: 3600m³/h;
- Marabá Pioneira: 300m³/h.

Regarding the flow captured

- Nova Marabá: 900 m³/h from the well and 800m³/h from the surface, totaling 1700m³/h;
- Marabá Pioneira: 300m³/h.

Regarding the flow produced

- Nova Marabá: 1700m³/h;
- Marabá Pioneira: 280m³/h.

Regarding the outflow of the pumping stations of the WTPs

- Nova Marabá: Three pumps of 1500m³/h, but only one works at a time;
- Marabá Pioneira: 300m³/h.

The capacity of the supported reservoirs

- Nova Marabá: Two reservoirs with 3000m³ each, totaling 6000m³;
- Marabá Pioneira: A reservoir with 150m³.

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Regarding the supply sectors and their elevated reservoirs:

- Nova Marabá Sector: With two elevated 1000m³ capacity each, totaling 2000m³;
- Novo Horizonte Sector: With an elevated capacity of 1000m³;
- Laranjeiras Sector: With an elevated capacity of 1000m³;

All these sectors are supplied by the Nova Marabá ETA. The last sector is the Marabá Pioneira Sector, without an elevated reservoir, with direct pumping.

Pumping Flow for Each Sector

- Nova Marabá Sector: two 780m³/h pumps, totaling 1560m³/h;
- Novo Horizonte and Laranjeiras Sector: 880m³/h;
- Marabá Pioneira Sector: The same produced by ETA: 280m³/h.

Regarding the daily pumping period for each sector:

- Nova Marabá Sector: 6 pm;
- Novo Horizonte Sector: 8 hours;
- Laranjeiras Sector: 3 hours;
- Marabá Pioneira Sector: No elevated reservoir.

DETECTION OF WEAKNESSES

Regarding the collection efficiency

With regard to withdrawal, no losses were detected in the Nova Marabá WTP, but there is a loss of 20m³/h in the Marabá Pioneira WTP. According to Kusterko et al (2018), water losses in the water supply system are defined as the discrepancy between the amount of water produced and the amount measured at the points of consumption. These losses can manifest themselves in various phases of a water supply system, from the collection process to the final delivery to the point of consumption. These losses are justifiable due to the age of the WTP, which is responsible for the deterioration of pipes, reservoirs, decanters and filters, and if there is no periodic maintenance of these facilities, significant losses will occur.

When it comes to the relationship between collection and treatment, there are no problems with the Marabá Pioneira WTP, but in the Nova Marabá WTP, there is a

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considerable problem in this aspect, given the difference of 1900m³ between the flow captured and the treatment capacity of the Station.

COSANPA was asked about this discrepancy, and the answer received was that it occurs due to the age of the catchment well, which has not been expanded for more than 40 years and is no longer capable of giving the flow demanded by the population, also explaining the presence of pumps on the surface of the Tocantins River for auxiliary catchment.

Regarding the capacity of treatment of WTPs

As discussed in the previous item, the Marabá Pioneira WTP is operating at full capacity, treating all the water collected, and there are no problems at this point.

As for the Marabá Pioneira WTP, it is not operating at full capacity, but this is due to the existing problem in the collection, which is insufficient, and there is also no margin to point out problems in this aspect.

Lifting efficiency

The Marabá Pioneira SAA has a higher elevation flow than the WTP, which is sufficient to supply the reservoir.

The Nova Marabá SAA has a lower elevation flow than that produced by the WTP, thus being insufficient to drain the treated water in a timely manner.

The capacity of the supported reservoirs

The supported reservoir of the Marabá Pioneira SAA has a capacity equivalent to half of the flow distributed in one hour, being applicable as the system's lung, according to Netto (2015), with no problems in this scenario, but not very efficient for emergency reserve

As for the Nova Marabá SAA, the capacity of the reservoirs is four times higher than the volume they receive per hour, and is also sufficient to fulfill their function and functional for emergency reserve.

Capacity of elevated reservoirs

The SAA Marabá Pioneira does not have elevated roads.

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The SAA Nova Marabá, in all sectors, has reservoirs with a capacity higher than that pumped in one hour for them, but lower than that supplied according to the total daily time, and it is possible to say that they fulfill the function of lungs properly, but there is no margin for emergency reserve.

Distribution efficiency

These points were worked on qualitative data due to the absence of mathematical and statistical information from COSANPA about the system. The analysis is limited to micro-measurement, consumption estimates and water reservoir levels. These data are also non-existent given the absence of any of these three materials and methods available to the concessionaire.

The failure in micromeasurement is the driver of a series of other problems, such as the impossibility of detecting losses that are not visible to the naked eye, such as water theft and minor leaks.

Another problem that this issue brings is the impossibility of knowing about the water demand of the addresses. The pumping periods for each elevated highway were chosen empirically and vary greatly depending on the time of year, reservoirs full before the total time or complaints of lack of water in the sectors.

The absence of technologies that monitor reservoir levels further contributes to this scenario. If these heights were aware, it would be possible to predict where water will be lacking more efficiently and effectively.

Finally, as there are not even estimates of consumption by the concessionaire, it becomes very difficult to determine what were, are and will be the water demands of the municipality. Without this information, it will be a great challenge to solve the issue of shortages and rationing in the municipality.

PROBLEM X OCCURRENCE RELATIONSHIP

Tables 2 and 3 show the relationship between problem and occurrence in each of the systems. These relationships took into account column 1 of table 1 of this study, which surveys all possible problems, now pointing out the occurrence or not of these in each case studied. The solutions were proposed according to the context in which the systems are located in item 5.4.

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Table 2: Problem x Occurrence relationship matrix SAA Marabá Pioneira

Problem	Occurrence
Insufficient withdrawal	-
Insufficient treatment	-
Inefficient lifting	-
Low capacity of supported reservoirs	X
Low capacity of the raised reservoirs	-
Insufficient or no micro-metering	X
Failure to measure the level of the reservoirs	X
Failed or missing consumption estimation	X

Source: Authors, 2023

Table 3: Problem x Occurrence SAA Nova Marabá Relationship Matrix

Problem	Occurrence
Insufficient withdrawal	X
Insufficient treatment	-
Insufficient elevation	X
Low capacity of supported reservoirs	-
Low capacity of the raised reservoirs	X
Insufficient or no micro-metering	X
Failure to measure the level of the reservoirs	X
Failed or missing consumption estimation	X

Source: Authors, 2023

CORRECTION OF WEAKNESSES

Regarding the efficiency of abstraction

The withdrawal does not have major problems in the SAA Marabá Pioneira, and the detected loss can be solved with an inspection of the internal pipes and structures of the WTP

Now this issue is potentially the biggest problem of the Nova Marabá SAA, since it is not operating at peak due to this failure, and not only it, but the entire system suffers because it lacks water.

The solution to this point can come either in the construction of another well, or in the addition of more surface pumps in the river, and the power needed for the WTP to be able to operate at full capacity is, according to Netto's equation (2015), considering an efficiency of 75% and a head of 12 meters is approximately 113 hp.

COSANPA also informed that it is working on this fragility with the acquisition of new underground pumps.

Regarding the capacity of treatment of WTPs

As there was no significant detection with the data obtained in this work, there is no need to propose improvements for the Treatment Plants.

Lifting efficiency

The elevation of the SAA Marabá Pioneira is higher than the flow produced by the ETA, thus being sufficient.

The elevation of the SAA Nova Marabá, therefore, has a flow 200m³ lower than that produced by the Treatment Plant, however, this failure is easily correctable with the periodic connection of a second pump to compensate for this discrepancy, not being a serious issue.

Capacity of supported reservoirs

As for the supported reservoirs, it is suggested the construction of a new reservoir for the SAA Marabá Pioneira so that it can more effectively fulfill its allocation of emergency reserve, preventing the population from running out of water.

Capacity of elevated tanks

For the elevated reservoirs, it is also suggested the construction of new reservoirs, because even though the reserve is not the main attribution of these, due to the fact that there is no knowledge about micromeasurement and water levels, a greater quantity of these structures will better ensure, for now, the continuous supply of water resources to homes.

Distribution efficiency

With regard to the distribution network, the initial proposal is for the concessionaire to carry out a technical-scientific study in order to determine a methodology for estimating water consumption. This study will partially solve one of COSANPA's greatest difficulties today, which is to know where there will be a lack of water and will serve as a subsidy for the sizing of level sensors and micro-measurement equipment that should come in the future so that this problem can be solved definitively.

CONCLUSION

Water is a fundamental right of the human being, and it is mandatory to supply it in sufficient quality and quantity to meet the demands of the population. With a view to this criterion, this work found serious flaws in the SAA of Marabá, especially in the part of collection and distribution network. The catchment is in a situation of extreme

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discrepancy with the real capacity to treat the WTP, seriously impairing the efficiency and effectiveness of the rest of the system, being the main responsible for the insufficiency of the supply, followed by the absence of technologies in the distribution network, which does not have any technique, study or knowledge for its management, its maintenance is done exclusively in a corrective manner and when a large leak is detected with the naked eye: All other problems are currently undetectable due to the lack of knowledge of the characteristics of the network.

Finally, it is concluded that the Marabá Water Supply System has great potential to work correctly following all the necessary guidelines, but there are two conflicting scenarios: One endowed with high technologies with a great potential wasted by the old and dated front, which in addition to everything delivers signs of lack of proper maintenance. In order for the problem of this research to be definitively solved, it is proposed that COSANPA consider evaluating the improvements proposed here through technical-scientific studies to prove their technical, economic and environmental feasibility and then implement them in the best possible way, offering access to the environmental good to all and with the necessary quality.

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