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Understanding water infrastructure and its constitutive role in configuring social dynamics in small towns

A case study in Moamba, Mozambique

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Master of Science Thesis
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Abstract

This research is aimed at contributing to the understanding of water infrastructure, particularly in the way it shape everyday practices and social dynamics. Its particularity lies in addressing the study of water infrastructure beyond its pure materiality. Despite the high degree of technical development in the disciplines used in the water sector, in practice, the behaviour of water infrastructure remains in a high degree of uncertainty, and the outcomes that it brings in terms of social dynamics are to a great extent unpredictable. We will never have complete control over the water infrastructure because we cannot prevent it from being constantly modified. I show in this thesis that changes are made in every single stage water infrastructure pass through, from its design, to its construction process, in the way it is operated and through further modifications to extend it and correct its malfunctions. Since the physical and institutional environment is always changing, the actors that interact with the water infrastructure are constantly tinkering with it in order to make it fit in their changing conditions. These are not only planned actions aimed at fulfil specific goals and interests in the long-term, but also pragmatic actions exerted to solve everyday challenges in an ad hoc and much improvised way.

On the other hand, actors are constantly modifying water infrastructure also because it is emergent in time and space and it is not possible to know in advance the way it will behave. This unpredictable nature is partially explained by the fact that the pretension of water infrastructures being precise artefacts, designed through rigorously and accurate engineering calculations based on complete, detailed, and exact data of the environment in which it will function, rarely happens in practice. But mainly because water infrastructure is never completely dominated by human will. It is tenacious and engineers, operators and water users are engaged in a permanent fight to make water flow towards the intended direction (or trying to prevent water from escaping one particular area), they are always repairing leaks and trying to correct malfunctions. On the other hand, because of the great diversity and number of practices the infrastructure connects, the outcomes of the changes in infrastructure are largely unpredictable. In this sense, this research shows that water infrastructure is contingent in nature. Hence, since we do not have certainty in the way it will function, the practices of the actors that built and modify water infrastructure are implemented in a logic of trial and error, and can be catalogued as experimental.

Finally, this thesis shows the role played by water infrastructure in processes of societal change. By acting was wellsprings of power, water infrastructures give even to the less powerful actors the chance to participate in contestation processes, challenging and reconfiguring the power dynamics in which they are immersed. Water infrastructure has also proven to be a major factor at reconfiguring the social dynamics of its environment. By shaping the households conditions to access water, the infrastructure provides the foundation for the development of specific forms of social relationships among the residents of a neighbourhood, promoting, as well, the development of specific forms of social organization to the production and periodic renewal of collective hydraulic property.

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CHAPTER 1

Introduction

The purpose of this research is to explore the implications of a socio-technical ontology of water infrastructure for theorizing its role in shaping processes of socio-nature change. In other words, I am focus on increasing our understanding of water infrastructure, particularly in the way it shape everyday practices and social dynamics, by taking its study beyond its mere materiality. But why it is necessary to study water infrastructure beyond its physical characteristics? Why we need to conceptualize it as something more than an ensemble of artefacts that have been put together, for example, to produce and distribute drinking water? One answer to these questions points towards practical implications for policy making and the implementation of infrastructure projects. Despite the high degree of development achieved in fields such hydraulics, mechanical engineering, biochemistry, information technology and other disciplines used in the water sector, in practice, the behaviour of the infrastructures that are built still result in a high degree of uncertainty. The way in which water infrastructures functions and the outcomes it brings in terms of social relations are to a great extent unpredictable. I want to understand this contingent nature of water infrastructure better as it also opens up space for contestation and alternative trajectories of change in society.

On the one hand, the image of modern water infrastructures optimal artefacts, carefully designed through rigorous and accurate engineering calculations based on complete, detailed, and exact data of the physical environment in which it will function, stands far from daily engineering practices. On the contrary, the use of standard designs and rather rough "rules of thumbs" applied indistinctly to different context seems to be a common approach in engineering (Tavengwa, 2017; Molle et al., 2009). On the other hand, no single actor will ever have complete control over water infrastructure because they cannot prevent it from being constantly modified by other actors and its biophysical environment. In fact, as I show in this thesis, there are changes in every single stage of water infrastructure development; from its design to the process of construction; in the everyday practices in which it is operated and through further modifications implemented in order to extend the infrastructure; in attempts to correct its malfunctioning;, and adaptations to the changing features of its physical and institutional environment. As such, and because of the great diversity and number of practices the infrastructure connects, the outcomes of the changes in infrastructure are largely unpredictable, or as Jensen and Morita state: *"planned and foreseen by no one"* (2016: p. 5).

The second reason has a more epistemological character: it is not possible to reach a good understanding of the role played by infrastructure in shaping society without addressing the fact that infrastructures are in inherently social and technical. Sahlins (1972) showed that during most part of human history, labor has been more significant than tools, and the efforts of their producers more significant than their simple equipment. In consequence, it is not mere technology, but technology in concert with the social coordination of labour that needs to be studied. Infrastructures form part of particular technological activity systems, emerged from

the *"combination of technical artefacts, regulatory frameworks, cultural norms, environmental flows, funding mechanisms, governance forms, etc. that get configured in particular ways in particular places at particular times"* (Obertreis et al., 2016: 172). This means that great part of the sociotechnical systems will remain invisible and silent if we only look at their artefacts. Socio-technical systems are also about knowledge, including in great extension visual/spatial thinking and knowledge, experiential learning and analogical reasoning in contrast to linguistic/written cognition, and the massively complex network the system mobilizes. This is the reason why it would be impossible to deduce the complexity of a sociotechnical system to its tools (Pfaffenberger, 1992).

With regard to the idea that water infrastructure is never a totally finish product, never a static object, I adopted the thesis that water infrastructure is pragmatic, contingent and experimental. Pragmatic in the sense that infrastructure is not only the product of planned actions aimed at fulfil specific goals and interests in the long-term, but also the product of actions exerted to solve everyday challenges in an ad-hoc and improvised way. By contingent I mean that water infrastructure is in a great extent unpredictable in the way it functions, producing unforeseen events and outcomes. Finally, I say water infrastructure is experimental because since we do not have certainty in the way it will function, it develops in a logic of trial and error (Tavengwa, 2017: 7).

Having explained the exploratory character of this research project in an attempt to contribute to theory through empirical research, it is worth explaining why I choose to conduct this study in a small town. Despite that very often small towns are considered by governments around the world as urban spaces (Kudva, 2015), the category of "small towns" arisen in the water and sanitation sector to denominate the human settlements that exists at the intersection between the rural and the urban (Adanak, 2013; Adank and Tuffuor, 2013; Pilgrim et al. 2007). In their large diversity, small towns are characterized by dynamics of constant change and growth that leads its residents to tinker with the water infrastructure in order to fit their changing needs. That is why the access to water within small towns is believed to present a wide variety of simultaneous options (Moriarty et al. 2002). According to Moriarty et al. (2002), in small towns water has a wider range of potential uses and is much more affected by the behaviour of people due to its greater population density, in comparison with rural villages. In consequence small towns are potentially more dynamic than rural villages and established urban centres, making it much more difficult to predict their evolution over time.

I find this potential at offering more opportunities to observe changes in the form, materiality, layout and the functioning of the water infrastructure in Moamba, the small town selected to conduct the research. Moamba is the headquarter of the district of the same name, in the province of Maputo, in the Republic of Mozambique. According to Mozambican National Institute of Statistics, by 2017 this district would be the place of residence of 71,003 inhabitants (INE; 2010). It is located on the intersection of the National Road Nº4 and the railroad that links Mozambique and Republic of South Africa, which makes this town a corridor of persons and goods. This has been a main factor in its process of rapid and unplanned demographic growth (Universidade Eduardo Mondlane; 2017).

In accordance with my theoretical approach, I decided to use the comparison of the different stages of the water infrastructure as a methodological device. In this way, I tried to capture the way in which the infrastructure develops in time and space. In practice, this has meant comparing design maps with the characteristics of the built infrastructure, and these

characteristics with the way the infrastructure works. Likewise, I have contrasted the prescribed operating practices with the actual operating practices. I have incorporated this methodology in the structure of this thesis, presenting in Chapter 4 an analysis of the water supply system in its entirety, detailing its evolution through different historical stages and the linkage of these changes with major political process that inform the passage of Mozambique form being a Portuguese colony to be an independent country. In Chapter 5 I zoom into at neighbourhood level, providing more detailed information about the contrast between the designed and the built infrastructure, as well as the practices that shape the way it is operated. Here I also analyse further the modifications implemented in the water distribution network. In Chapter 6 I zoom in further to a block of streets that are characterized by the extension of the water supply system that its residents made utilizing second-hand pipes. Here I analyse the way the extension in the network were done and its impacts on the social dynamics of the neighbourhood. Finally, this thesis addresses the analysis of the water infrastructure at household level, trying to show the connection between the domestic infrastructure and the functioning of the infrastructure built as part of the larger water supply system, as well as the social implications the differentiated access to water brings to these families.

1.1. Research objective

The objective of this research project is to contribute to the theorization of water infrastructure, by exploring the implications of a socio-technical ontology to understand its contingent, experimental and pragmatic nature. By doing so, this research project is also aimed at contributing to enrich the understanding of the constitutive role of infrastructure in the processes of societal change in small towns.

1.2. Research questions

Main question: How can we understand the constitutive role of water infrastructure in the dynamics of small towns?

Sub-Questions:

1. What are the changes in the form, materiality, lay-out and functioning of the water infrastructure?
2. When, how, why the changes in the water infrastructure occurred?
3. How these changes (re)configure socio-nature relations?

CHAPTER 2

Literature Review

In this section, I present a review of the ways in which infrastructure has been conceptualized with the goal of delineates my own conceptual framework. This review starts with what I will call here the "engineering perspective". According to this perspective, water infrastructure is conceptualized as rigorously and precise artefacts designed with a long-term vision to solve specific problems (Ashcraft & Mayer, 2016; Molle et al., 2009; Grumbine & Xu, 2011; Le et al., 2007; Cook & Bakker, 2012; Grey & Sadoff, 2007; Boelens & Vos, 2012), based on complete and exact data of the physical environment in which it will functioning (Masseroni et al., 2017: Koetch et al., 2014). By perfectly satisfying the long-term objectives for which it was created, the water infrastructure is portrayed as complete and static. However, the empirical evidence proves that this vision of water infrastructure is in the best of the cases incomplete, in the sense that water infrastructure is in a large extent experimental and contingent in nature, in opposition to rigorously and precisely calculated and designed; and also pragmatic, in opposition to the idea that is designed with a long-term vision: infrastructure is always changing to adapt to the conditions of its environment (Tavengwa et al: in press).

In contrast to this "engineering perspective", there is an established body of literature that addresses infrastructure as artefacts that are in nature both, social and technical. According to this idea, it is not possible to reach a good understanding of infrastructure without going beyond its mere material and technical characteristics. Infrastructures consist themselves in societal and ecological dimensions because they are components of 'socio-technical systems'. The latter is a concept collectively developed by various scientific disciplines[1] to denominate a distinctive technological activity system that emerges from the linkage of techniques and material culture to the social coordination of labour (Pfaffenberger, 1992: 476). The sociotechnical systems are heterogeneous constructs that articulate social and non-social actors in a seamless web, where the social is indissolubly linked with the technological and the economic (Hughes, T. 1989; Hughes, T. 1990). In this view, infrastructures are considered as *"a combination of technical artefacts, regulatory frameworks, cultural norms, environmental flows, funding mechanisms, governance forms, etc. that get configured in particular ways in particular places at particular times"* (Obertreis et al., 2016: 172).

The ideas associated with the sociotechnical system concept leave a strong mark and have developed into other schools of thought. The idea for instance that society, nature, and technology co-evolve has been further developed for urban geographers and political ecology researchers, who demonstrate how infrastructure plays a key role in the production of urban space and nature (Swyngedouw, 1997; Swyngedouw, 1999; Swyngedouw 2006; Gandy, 2005; Graham and Marvin, 2001; Heynen et al., 2006; McFarlane and Rutherford, 2008; White and Wilbert, 2009a). Under this view, infrastructures are the outcome of metabolism processes "*in which social and natural processes combine in a historical-geographical production process of socionature, whose outcome (historical nature) embodies chemical, physical, social,*

[1] The sociology of scientific knowledge, the history of technology and the science and technology studies

economic, political, and cultural processes in highly contradictory but inseparable manners" (Swyngedouw, 1999: 447). These socio-nature processes not only produce new natures but also new social relations (Heynen et al., 2006). However, in this literature the focus is on how infrastructure is shaped by social relations of power. For these scholars infrastructure mirror and reproduce the uneven distribution of power and opportunity in society, which is intersected with categories of race, ethnicity, class, and gender (Swyngedouw, 2009; Swyngedouw, 1997; Kooy and Bakker, 2008; Truelove, 2011; Sultana, 2011). However, infrastructures are at the same time spaces of contestation (Anand, 2011).

I has pointed out that this conceptualization of water infrastructure is over-politicised, in the sense that presents a deterministic view in which water infrastructure can be interpreted as a tool of social engineering, while the evidence (Furlong, 2010; Jensen, 2010; Berg, 2001) supports the argument that "*water infrastructure involves a constellation of different powers to such a point that it is hard to steer society in linear development and attribute the direction of outcome to a single power"* (Tavengwa, 2017: 6). In other words, in this political view water infrastructure only mirror and reinforce power relations but does not explain how this happens, and neither explain how infrastructure also reconfigures social relations of power. Urban geography and political ecology also overemphasises infrastructures as engineering process and overlooks its experimental and contingent character (Jensen and Morita, 2016); without paying too much attention to the fact that actors are continuously tinkering with the infrastructure to suit their changing needs (Tavengwa, 2017, Furlong, 2010; Meehan, 2014).

Furlong (2010) also rescue some critics elaborated from the Science and Technology Studies. Particularly from the Large Technical System (LTS) studies, it has been pointed out that the geographical studies of infrastructure, using a political economy, overlook the role played by key actors in shaping the change in sociotechnical systems. By quoting to Coutard, Furlong state that *"despite most arguments being economic it is rather customers' and regulators' attitudes toward networks that 'are essential to explaining current evolutions' in infrastructure"* (Furlong quoting Coutard; 2010: p. 465). According to Furlong (2010), other explanatory factors in socio-technical change are the conflicting interests of social groups, and the logic of building science, the relationship between design, financing, construction, and management, and the interaction of new technologies with the LTS into which they are introduced. Finally, she mentions users as an important explanatory factor of socio-technical developments (Furlong, 2010: 465).

The approach used by urban geographers and political ecologist is based on the assumption of the connection between technical and social change. But in this conceptualization the role attributed to infrastructure is passive. Here infrastructure is only a mean, a space or a terrain in which the daily-life struggles of power occurs. In contrast with this view, the concept of material agency has been developed in the Actor-Network Theory (ANT), which postulates the idea that *"anything that does modify a state of affairs by making a difference is an actor or, if it has no figuration yet, an actant … or more precisely, participants in the course of action waiting to be given a figuration"* (Latour, 2005: 71). "Things" in this theory as opposed to humans "*are hybrids or quasi-objects (subjects and objects, material and discursive, natural and social)* (Swyngedouw, 1999: 447) *"intermediaries that embody and express nature and society and weave networks of infinite liminal spaces"* (Swyngedouw, 1999: 445).
To better illustrate this network that interweaves humans and non-humans in a course of action I would like to quote an example given by Swyngedouw:

> *"… if I were to capture some water in a cup and excavate the networks that brought it there, "I would pass with continuity from the local to the global, from the human to the nonhuman" (Latour 1993:121). These flows would narrate many interrelated tales, or stories, of social groups and classes and the powerful socioecological processes that produce social spaces of privilege and exclusion, of participation and marginality; chemical, physical, and biological reactions and transformations, the global hydrological cycle, and global warming; capital, machinations, and the strategies and knowledges of dam builders, urban land developers, and engineers; the passage from river to urban reservoir, and the geopolitical struggles between regions and nations. In sum, water embodies multiple tales of socionature as a hybrid* (Swyngedouw, 1999: 445 - 446).

The main critic made to ANT is that *"Semiotically, as the actor-network approach insists, there is no difference between human and nonhuman agents: the human and nonhuman agency can be continuously transformed into one another* (…) *We, humans, differ from nonhumans precisely in that our actions have intentions behind them, whereas the performances (behaviours) of quarks, microbes, and machine tools do not"* (Pickering, 1993: 565). However, even for Pickering this does not seems important since he argues that in practice it is not necessary to have insight into the intentions of things. In the end *"human agency is, just like material agency, temporally emergent* (...) *it, too, simply emerges in the real time of practice* (Pickering, 1993: 566).

Later on, the response of Latour (2005) was that the idea of non-humans as participants in the course of action does not mean that they determine the action. "*ANT is not the empty claim that objects do things instead of human actors…*" (latour, 2005: 71 -72) and later on *"ANT is not, I repeat is not, the establishment of some absurd 'symmetry between humans and non-humans'. To be symmetric, for us, simply means not to impose a priori some spurious asymmetry among the human intentional action and a material world of causal relations"* (Latour, 2005: 76).
From my perspective, this theoretical debate does not seem a fertile terrain on its own. I concur with Tavengwa (2017) that it makes more sense to conduct empirical studies that describe in detail what water infrastructure is and helps to do, and thus analyze how a concept like material agency helps us understanding socio-nature change. For Pickering (1993) "*material and human agencies are mutually and emergently productive of one another"* (Pickering, 1993": 367). Which means that their contours only can be delineated in its interaction, when the material oppose resistance or accommodates to the human will. However, as Jensen and Morita (2016) has highlighted "*infrastructures are at once 'objects that create the grounds on which other objects operate' and 'also the relation between things'"* (Jensen and Morita, 2016: p. 5). This, in theory, opens a range of different situations in which it is possible to observe material agency from the interaction of the non-humans components of the sociotechnical system. Three possible ways to study this in the case of water infrastructure: in its interaction with the environment; in the interaction of its physical components; and in its interaction with the rest of the network of which it is part. It is my interest to develop this line of inquiry.
The main virtue of this approach is that allows us to overcome the dichotomy of studying sociotechnical change paying attention only to humans or only to objects. The ANT postulates the dissolution of these categories by emphasizing the hybrid nature of the components of the network: subjects and objects, material and discursive, natural and social. This, of course, is coherent with the idea that the different components of a sociotechnical system co-shape each

other. The difficulty resides, however, in justifying the arbitrary selection of the network section that will be studied in an empirical research.

To conclude this section I would like to present the way I going to use the concepts abstracted from this literature review. In the first place, I will understand *agency* as the capacity to act and modify a state of affairs by making a difference (Latour, 2005: 71). In the case of *material agency*, this capacity to act follows from its quality of being force-full: *"Equipment is not effectible 'because people can use it': on the contrary, it can only be used because it is capable of an effect, of inflicting some kind of blow on reality''* (Meehan, 2014: 217). This does not mean that objects do things 'instead' of human actors, but certainly, they do participate in the course of action (Latour, 2005: 72) and regularly even against human will. This is the resistance that Pickering talks about, but while for this author *"material and human agencies are mutually and emergently productive of one another"* (Pickering, 1993: 365) in my hypothesis it would be also possible to delineate the contours of material agency by observing the interaction between objects, to see how one acts on or through the others.

In relation to human agency, human actions and practices can be classified as goal-oriented in the sense that are guided by intentions (Pickering, 1993); and unintentional, in the sense of non-rational everyday practices embedded in cultural routines, actions that people do without being entirely conscious about them (Cleaver and de Koning, 2015). Among the intentioned actions and practices, I distinguish *strategic actions* from *pragmatic actions*. In the frame of this research project, strategic actions are defined as planned actions aimed at fulfilling specific goals and interests in the long-run. By pragmatic actions, on the other hand, I mean conscious actions exerted to solve everyday challenges in an ad hoc and improvised way, in opposition to rigorously calculated (see also Tavengwa, 2017: 7).

Here the term *contingent* will be used to refer to unforeseen events and outcomes, not consciously planned, that happens by chance, usually after initial conscious decisions. By *experimental*, I refer to something that is the product of processes of trial and error and in consequence that has uncertain effects and outcomes (Tavengwa, 2017: 7). In conclusion, water infrastructure is an ensemble of sociotechnical artefacts, emergent, and contingent in nature because people tinker with it for strategic and pragmatic reasons, but also because the biophysical environment is not static and never fully known. In consequence, water infrastructure development is always experimental.

CHAPTER 3

Methodology

3.1. Epistemological considerations

In order to explain the epistemological line followed in this research project I will return to the citation of the beginning of this text: there is not such a thing as 'objective' truth, in the sense of valued-free, coming from someone without interest or background. Knowledge always *"comes about through situated perspectives that need to be made as explicit as possible"* (Zwarteveen and Boelens, 2014: p. 148).

There are two ideas that I want to develop from the previous paragraph. One is that scientific knowledge, rather than absolute truth, is an ensemble of arguments built on empirical evidence, which in turn is produced through sets of scientific procedures and methods. The second is that the knowledge I aimed to produce will be a product of my own socially positioning. In this sense, the objectivity I attempt to achieve does not mean impartiality or conclusive evidence but derive from the act of making these procedures and methods explicit and transparent, justifying why they were chosen. In this way other scientists can scrutinize the knowledge claims I will put forward, complementing or contradicting them with other empirical evidence or different reasoning (Brown, 1988: Limb and Dwyer, 2001). Trying to be coherent with this idea, in the next sections of this chapter I will make my research choices explicit, explaining why and how the method for data collection and analysis were chosen. Also in the process of analysis and interpretation, I will point out as transparent as possible the logic used in establishing the relations between the evidence and the line of argumentation that will emerge from it. At the end of the document, I will include a reflection on how these choices shaped the outcomes of my research. Following this line of thought, it is also important to include throughout the report reflections on how my social positioning as a researcher affected the ways in which interviewees related and responded to me. How social categories such as my race, my age and nationality, my gender, the fact that I am coming from a European education institution, etc. affect the way they interact with me. In summary, I will try to answer in which ways these characteristics could have conditioned their behaviours and their answers.

The production of reliable data is also associated with four criteria: credibility, transferability, dependability and confirmability (Babbie and Mouton, 1998: 277 - 278). For the authors cited, *credibility* refers to the need for compatibility between the constructed realities that exist in the minds of the interviewees and those that are attributed to them by the research. In order to achieve this criterion, I will resort to data saturation through a prolonged engagement in the field and persistent observations. Credibility also follows from triangulating the different source of data about different events, contrasting different points of view and using different methods to collect these data. Finally, I will pursue credibility going back to the source of the information to check if the data and the interpretation are correct. This also will allow me to

assess the intentionality of the respondents and to collect additional information, assessing the overall adequacy of the data. Transferability refers to compatibility between what the researcher writes and what the reader receives. To achieve this criterion I will provide sufficiently detailed descriptions of data in context and reports them to allow judgements about transferability to be made by the reader. Also, I will resort to purposely selecting locations and informants that differ from one another, in order to maximize the range of specific information to be obtained from and about a specific context. The criterion of dependability refers to the possibility of arriving to similar research findings when the research is done by another researcher with the same subjects and in the same context. In the frame of the current research project, the achievement of this criterion is limited to the supervision of senior academics. Finally, the criterion of confirmability refers to compatibility between the data collected and the research findings obtained. With this purpose I will use raw data as field notes, documents and interview recordings; data analysis products and records, as well as make process notes and references to interviews.

Table 1: Criteria and procedures used to achieve objectivity

Criteria	**Procedures**
1) Credibility: it must be compatibility between the constructed realities that exist in the minds of the interviewees and those that are attributed to them by the research.	*Prolonged engagement* in the field, until data saturation occurs. Persistent observation. Consistently pursue interpretations in different ways, in conjunction with a process of constant and tentative analysis. Look for multiple influences. Search for what counts and what doesn't. *Triangulation*. Collection of information about different events and relationships from different points of view, asking different questions, seeking different sources, and using different methods. *Members check*: going to the source of the information to check both the data and the interpretation. The aim: to assess the intentionality of the respondents, to correct for obvious errors, and to provide additional information. Assess the overall adequacy of the data.
Transferability, that refers to compatibility between what the researcher writes and what the reader receives.	*Thick description*. Providing sufficiently detailed descriptions of data in context and reports them to allow judgements about transferability to be made by the reader. *Purposive sampling*. Purposely selecting locations and informants that differs from one another, in order to maximize the range of specific information to be obtained from and about a specific context.
Dependability: possibility of similarity of research findings when research is done by other researcher with the same subjects and in same context.	Being supervised by senior academics.

Confirmability: this is compatibility between the data collected and the research findings obtained.	Using raw data as field notes, documents and interview recordings; data analysis products and records; making process notes; and referencing to interviews.

3.2. Research design

3.2.1. Object of study

The focus of my research is in the understanding of how water infrastructures shape social relations and transform the physical environment in the context of small towns. To generate answers to this questions I decided to use a particular piece of water infrastructure as my unit of analysis, and try to trace the effects that the change in its form, materiality, lay-out and functioning has had in the social relations and the environment. This decision has two implications: first the adoption of an object-oriented approach and second the use of the case study as a general research strategy. In terms of Burawoy (1991) I am not looking for statistical significance to construct a theory that explain the similarities of different social situations but explanations of particular outcomes, historically specific causalities, where the *"The importance of the single case lies in what it tell us about the world in which it is embedded* (...) *about the society as a whole rather than about the population of similar cases"* (Burawoy, 1991: 281). Within the overall case study research design I will also use ethnographic methods to study the human practices around the infrastructure. This decision respond to my theoretical understanding of material agency: following Pickering (1993) one way to delineates material agency would be chasing the dynamics of accommodation and resistance that objects impose to human will. To better understand how water infrastructure resists or accommodates to the will of their users, the engineers that design it and the people involved in its operation and maintenance, I need to understand the meanings that organize their practices.

Paxiography is a methodological approach born from the theory of practice (Ortner, 1984) and the use of ethnographic methods, such as the participant observation; but instead of been interested in the ethno (culture) component it is focus on the analysis of 'praxis' (practice) (Burger, 2014). For praxiography, practices are *"meaningful, regulated, bodily movements, which depend on a related implicit incorporated knowledge* (…) *implicit or tacit knowledge which organizes the practice and gives meaning to it"* (Burger, 2014: 387). In order to find the knowledge implicit in the water infrastructure practices I resort to the use of "expert interviews" as a data collection technique and to study *"moments of crisis and controversies"* as the praxiography strategies suggested by Burger (2014). In my case study, these moments of crisis and controversies can be contexts of interruptions in the water supply service produced by breakdowns in the infrastructure. Adjustments in its functioning and reparation practices as well as practices of tinkering with the infrastructure can be addressed as moments of controversies in which the actors involved can explicitly discuss how each piece of infrastructure does or should do. According Burger (2014), there are two types of 'experts': those who has been participating in the practice on an everyday basis and those who has spent a considerable amount of time in observing the practice (Burger, 2014: 400). On the other hand, he explain that it is useful to study moments of controversy and crisis because during these moments the implicit knowledge of the practices often becomes explicated and articulated, because the participants of practices discuss and argue about whether new situations can be

accommodated into existing practices, if adjustments need to be made or new practices need to be introduced or invented (Burger, 2014: 395 - 397).

The recommendation of Burger goes in line with the Latour's advice of invent some tricks to *"make them* [objects] *talk, that is, to offer descriptions of themselves, to produce scripts of what they are making others - humans or non-humans- do"* (Latour, 2005: 79). These tricks consist in paying attention to specific situations such as 1) *innovations*, in which the new things objects do or allows to do are explicitly explained; 2) situations in which the use of an object is marked by the sense of *novelty*, because they are approached by *"users rendered ignorant and clumsy by distance - in time as in archaeology, distance in space as in ethnology, distance in skills as in learning"* (*ibidem*), or novelty situations created by the irruption in the normal course of action of strange, exotic or mysterious implements; 3) situations of accidents, breakdowns, strikes (fails in general), in which what the objects do became evident because they suddenly stop doing it (Latour, 2005; 80 - 81). I will use these recommendations as a guidance to identify general situations of change along the history of the water infrastructure studied to try to trace any possible form of material agency.

In the following lines I will summarize the virtues of the case study approach, particularly the extended version suggested by Burawoy (1991), and how they fit with the requirements imposed by my research questions. According to this author, one should extend the case study in five different dimensions. The first one consist in extending the research towards the researcher itself. In concordance with my epistemological point of view, the researcher always will be socially situated. In consequence, I need to explicitly position myself in relation to the object and context of the study, reflecting on how my own limitations, background and standpoint can generate possible partialities and biases. The second dimension consists in extend the research over the subject of the study. Instead of focusing on extraordinary phenomena, I will search for detailed insights abstracted from thick descriptions (Geertz, 1987) about everyday water infrastructure practices. The idea here is to go beyond the particularities of the case study and potentially generate broader claims and understandings. The third dimension is to extend the research in time. In my case this means to address the history of the water infrastructure to understand its current situation and its connection with the social relations in which it is interweaved. Extending the research in space is the fourth dimension. I has decided to study a specific piece of infrastructure in its "real-life context" (Yin, 2003). This implies to look beyond the case study area in order to capture connections with processes that happen at large spatial scales. Also means that I should look at the broader network of which the piece of water infrastructure form part to understand how the change in this infrastructure affects the other parts of the network and vice versa. Finally I should extend the research in theoretical terms. This means to make an effort on building on pre-existing theories. In my case, drawing on conclusions that contributes to the understanding of the ontology of water infrastructure and its role in processes of societal change in small towns.

3.2.2. The case study selection

How I explained before, "small towns" is a category developed in the water sector to denominate geographical areas that represent the encounter of the urban and the rural, a reality particularly common in the global south that is expected to increase in number and importance in the coming years, especially in Africa and Asia. Taking this into consideration I selected the district of Moamba, in the province of Maputo, Republic of Mozambique, to conduct my case study research. The selection of this district respond to the concordance of its characteristics

with those attributed to small towns (see the introduction section of this text), but also to pragmatic reasons.

In relation to its characteristics as small town, according to the projections of the Mozambican National Institute of Statistics (INE in Portuguese), by 2017 Moamba will harbour 71,003 inhabitants (51.6% women). Because of its location, on the intersection of the National Road nº4 and the railroad that links Mozambique and Republic of South Africa, Moamba constitutes a corridor of persons and goods (INE, 2007). This is one of the main factors behind its characteristic dynamic of rapid change and growth, which is related to the situation of insufficient water supply to covert the increasing water demand. In this sense, one of the assumptions on which this research project is based is the existence of ad-hoc development of water infrastructure by the formal utility. This would be one of the characteristics that distinguish this small town from cities as Maputo, where the deficit in the water offer is covered by informal small scale water providers (Ahlers et al., 2013). In relation to the pragmatic reasons to choose Moamba as seat for the case study, this research accounts with the support from local partners (who facilitates the access to field site and the connections with possible informants), as well as the funding available for extensive fieldwork provided by the project SMALL-Water supply and sanitation in small towns.

The water infrastructure selected as unit of analysis is the water treatment and distribution network of Moamba village, capital of the district with the same name. It was inaugurated on June 2013 to operate in a concession area with a population of approximately 24,650 inhabitants, with a coverage projected of 45%.

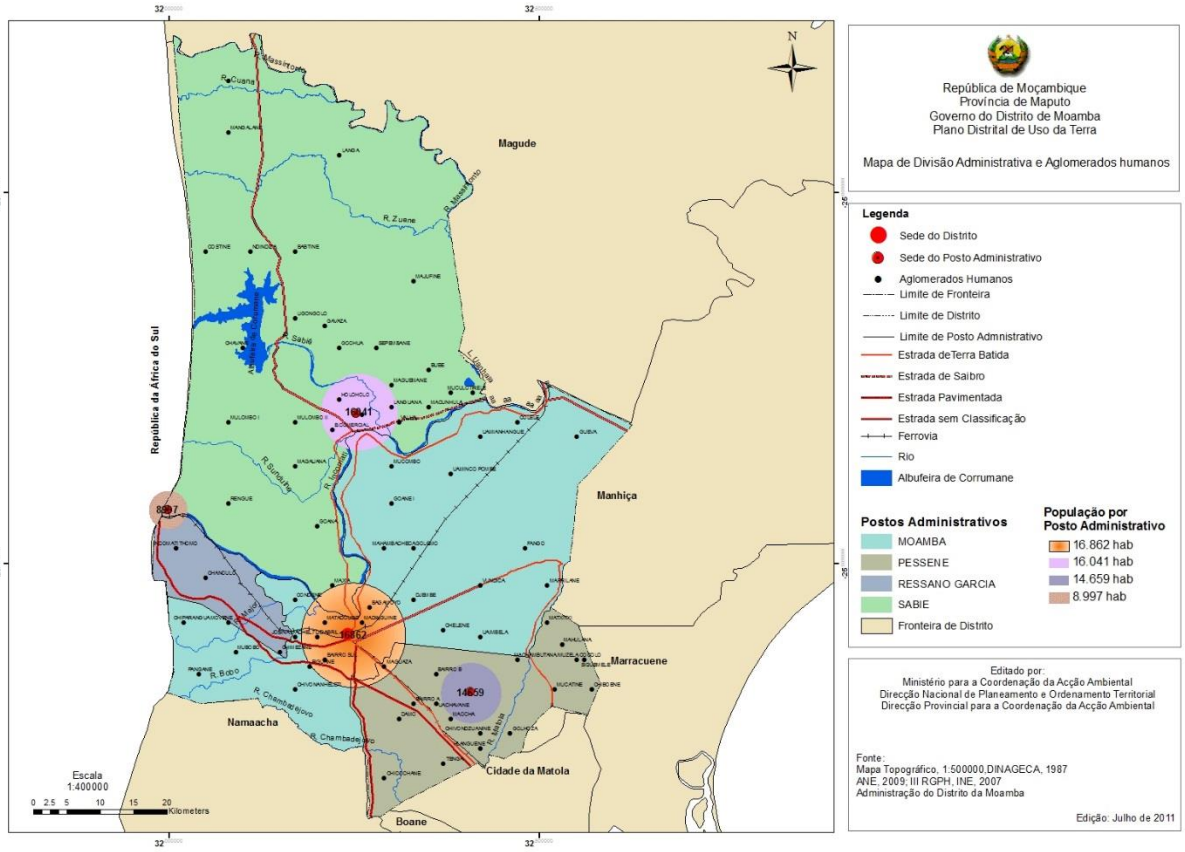

Figure 1: Map of Moamba District and Administrative Post

Source: Relatório De Água E Saneamento (Versão Final-Volume I). Elaborated by the Universidade Eduardo Mondlane in the context of the Project Water supply and sanitation in small towns.

3.3. Research approach

3.3.1. Data collection and triangulation

I have organized the pursuing of the information around three specific research questions: 1) what are the changes in the form, materiality, layout and functioning of water infrastructure? 2) When, how and why these changes in the water infrastructure occurred? And 3) how these changes reconfigure social relations and the physical environment? The information is presented by zooming into the characteristics of the infrastructure from the town level to the neighbourhood level, and from here to the household level. At the same time, the analysis of the water infrastructure evolution is presented from the oldest features of it, to the more recent changes.

Based on Tavengwa's work (2017) I am conceptualizing the change in water infrastructure in four stages: design, construction, operation and extensions and other modifications. The register of the changes in the form, materiality, lay-out and functioning of the infrastructure will follow from the comparison of the data collected for each of the four stages in the life-time of the infrastructure. I am assuming that the original design and every strategically planned further modifications made to the infrastructure are reflected in engineering maps, feasibility

reports, bill of quantities and other official documents. These are my data sources for the stage of design and the technic to collect this data is archive review. Clarification on the data found in this sources can be obtained through the testimony of engineers with knowledge in the issue. To verify the characteristics of the built infrastructure (second stage) I use three types of data collection technics. The first one is observation technics, through which I produce observation notes and audio-visual material (pictures and videos). The second technic is semi-structured interviewing, aimed at infrastructure users and people involved in the processes of design, construction, operation and maintenance of the infrastructure. The third data collection technic is the consultation of time-series satellite images through the software Google Earth. The data from the further extensions or modifications made on the infrastructure will be collected also through observation and semi-structured interviewing.

Answering the second question (when, how and why the changes in the infrastructure occurred?) implies to distinguishing between human actions on the infrastructure (that being intentional can be strategic, in the sense of planned to achieve long-term interest or goals, or more pragmatic) from the 'actions' or 'acts' of the physical components of the environment with which the infrastructure interact. This was done by collecting stories about how the infrastructure has change over time, from where I delineate the complex co-shaping relations between human and non-human acts and infrastructural change. I use in-depth interviewing to collect the testimony of witnesses of the infrastructure history; namely infrastructure users (and among them especially those who has intervened the infrastructure) and people involve in the design, construction, operation and maintenance of the infrastructure. I also use these interviews to produce time-lines that help to visualize (me and interviewees) the processes of change in the infrastructure and the possible connections with processes in other spatial scales. Finally, for the practices of infrastructure change occurring during the field work I produced thick description, to later develop an analysis aimed at identifying relations between human and non-human acts and infrastructural change. The technics of data collection I used with this purposes were observation technics and, audio-visual methods, as well as in-depth interviewing with the infrastructure users.

Finally, answering the third question (how does the changes in the infrastructure reconfigure social relations and physical environment?) implies to trace the water infrastructure acts, this is what the infrastructure is doing (or helps to do), and explain how these acts are connected with social relations and physical environment change. I traced the acts of water infrastructure in three ways. First According to Pickering (1993), material agency becomes evident in form of resistance and accommodation to human will. In this sense, I needed to make explicit the goals and intentions that orient human actions in using and modifying the water infrastructure. Here I used the praxiograhy methodology approach (Burger, 2014) to find the incorporated knowledge that regulate and give meaning to human practices. This helped me to understand in which ways water infrastructure is opposing resistance or accommodating to human will. Second, I captured this implicit meaning of practices by studying moments of controversy, disputes and crisis in which the way of use or modify infrastructure are explicitly addressed and discussed by the practitioners. Third, studying particular situations, such as innovations on the water infrastructure (what this changes imply for the users and the environment? what the innovation allows to do?), situations of novelty in which the normal course of action is altered (the focus was on how the practitioners react to deal with novelty) and situations of fail of the infrastructure, to see what the infrastructure suddenly stop to do.

I used observation to address the practices of infrastructure use and modification as well as to observe the behaviour of infrastructure users (and engineers if is the case) while discussing about what to do during moments of crisis and discrepancies, situations of novelty, infrastructure fail and innovation. I also used in-depth interviewing with the infrastructure users and engineers involved or familiarized with the design, construction, operation and maintenance of the infrastructure to ask about the activities exerted in the infrastructure use and change practices as well as interpretation of why they do so.

How I tried to show above, in answering each question I selected different sources of data and different data collection techniques; namely observation, documents review, in-depth and semi-structured interviewing, comparison of time series of satellite imagines and the use of photography and video recording. In this way I am generating space for contrasting and triangulating data, which allow me the identification of patterns, contradictions as well as get insights from different perspectives and registers of the same issues. The testimony of the interviewees will be contrasted with the data collected from the documents, such as the design maps, with the observations during the field work and with the satellite images. The testimony of the infrastructure users that modify the infrastructure will be contrasted with the testimony of the users that was witnesses of the modification practices and with the testimony of the specialists involved in the design, construction, operation and maintenance of the infrastructure. The contradictions, irregularities and everything that seems falling out of the pattern will be specials pints of enquiry.

3.3.2. Sampling strategy

In order to choose my interviewees I will use purposeful sampling. This is a sampling strategy described as the selection of individuals for study because they can purposefully inform an understanding of the research problem and the central phenomenon in it (Creswell, 2007: 125). Given that I only had in advance few references about who can have the data that I need to answer my research questions, I will use the snowball technique to identify *"…cases of interest from people who know people who know what cases are information-rich"* (Creswell, 2007: 127).

As I mentioned before, I have two main types of interviewees: water infrastructure users and specialist actors engaged with the design, construction, operation and maintenance of this infrastructure, such as engineers and operators. I chose them because I consider them both as experts in the subject. Among the infrastructure users I worked with people that has participated in practices of infrastructure modification. Participants and witnesses knows well about the characteristics and functioning of the infrastructure on the basis of everyday use practices. I asked them "*how they perform certain activities that are part of the practice. And we will attempt to receive data with which knowledge, motivations, or emotional states the practice is performed. In this process, the interviewee is forced to explicate his implicit knowledge"* (Burger, 2014; 400). On the other hand, in the actors involved in the design, construction, operation and maintenance of the infrastructure *"we seek assistance in the interpretation process, and will ask questions of the type 'why do you think that they are doing it in this or that way?* (…) [Users that participate in infrastructure change] *help to collect raw data, and co-produce first interpretations, while type two* [specialist and infrastructure users, witnesses of the change] *observer questions concern (often already settled) interpretations"* (Burger, 2014; 401).

The number of the specialist involved in the design, construction, operation and maintenance interviewed was determined by the availability of the persons with the knowledge required and a criterion of convenience for the research (suitability of the interviewees, accessibility, resources demanded to conduct the interviews). The people interviewed based on these criteria were mostly members of the current water utility company in Moamba. They are the general manager, who also participate in the development of the original design of the project to rehabilitate and extend Moamba's water distribution network; the person in charge of the site office in Moamba; two operators of the intake station; the technician responsible for the water quality in the system; one technician responsible for the hydraulic area; and one person which main responsibility was to dig as part of the works of repeating and extending the distribution network. In addition to the several interviews I had with these people I also had an interview with to people that worked in the construction process of the new Moamba's water distribution network, between 2011 and 2013. It was not possible to contact any engineer involved in this project.

The selection of the water users to interview was based on an exploratory phase during the fieldwork aimed at identifying the pertinent variables that could define different type of water users. The pertinent variables identified were related to the characteristics of the households in terms of the number of its members, their age, gender, and financial situation. On the other hand, I found also possible to distinguish between water users based on the type of infrastructure they have access to. In this sense, I distinguish between households with and without in-house water connections; between households connected to the water network administrated by the water utility company and those households connected to second-hand pipes installed by the water users by themselves. Finally, is possible to distinguish among households based on the water storage infrastructure they possess. For instance, to own a water tank with capacity to store $1m^3$ or more make the difference in terms of the water security of the families. Based on this criteria, I conduct interviews with different members of 22 households, among whom 21 were residents of the same neighbourhood. Additionally, I had interviews with the block boss of Quarteirão 11 and the secretary of Bairro Central. For the summarized version of the data collection set-up please refer to appendices.

3.4. Processing and data analysis

Answering the first question consisted in identify the changes in the form, materiality, layout and functioning of the water infrastructure studied. Hence, the main task consisted in comparing the characteristics of the water infrastructure in each of its stages (design, construction, operation, and extension/modification), identify the changes and their link with major political processes occurred in Moamba during this period. The data sources used were design maps, a map of the current water infrastructure I developed using Google Maps; the testimony of actors involved in the design, construction and operation of the water infrastructure, as well as the testimony of the infrastructure users; satellite imagines; and observation notes of the infrastructure itself and the practices of the actors that interact with it. To process this data I used the form, materiality, layout, and functioning characteristics of each stage of the infrastructure as categories to conduct a *Content Analysis*. In the case of the interviews the data was transform into interview narratives notes. For the rest of sources, the data was organize in the form of a descriptive text and feed into Table 5 (see Chapter 4). This table was designed to facilitate the visualisation of the components of Moamba's water supply system and its characteristics, distinguish different phases of development, serving to the

double purpose of facilitates the comparison of the characteristics of the infrastructure in its different stages and be a tool for data management.

Answering the second question (when, how and why the changes in the water infrastructure occurred?) implied to identify the changes in the infrastructure (task achieved in answering question 1), and identifying the processes in which these changes occurred. The reconstruction of these processes is presented in form of narrations which are composed based on the patterns identified in the users and the engineers' stories about how infrastructure changed over time. The goal here was to find connections between the human practices of infrastructure use and modification and non-humans acts in one side, and the changes in the infrastructure in the other. I used Thematic Analysis on the interview narratives notes to identify patterns and contradictions in infrastructure change processes.

The data contained in the interview narratives notes were also used in the production of time-lines in order to facilitates the visualisation of the linkages between the events of change in the infrastructure and other historic processes occurred in the country. Here again I used Thematic Analysis to the observation notes, interview narratives and the data abstracted from audio-visual material to identify processes of infrastructure modification and produce thick descriptions of them. I compared these descriptions to find the causes of the change in infrastructure.

To answer question three (how the changes in the water infrastructure reconfigure social relations and physical environment?) I proceed in a similar way. I will use Thematic Analysis to process the data in the interview narrative notes, identifying patterns and contradictions in the stories of change in the social relations and the physical environment of the infrastructure users. Based on the result of this analysis I composed a descriptive narration about these processes of change with the purpose to show and explain the connections between the changes in the water infrastructure and the change in the social relations and environment of the users.

CHAPTER 4

The evolution of Moamba's water treatment and distribution system

Before presenting the analysis of the evolution of the water infrastructure in Moamba, it is necessary introduce some general information about the place. The village of Moamba is the headquarters of the district capital, which have the same name. According to Mozambican National Institute of Statistics, by 2017 this district would harbour 71,003 inhabitants (INE; 2010). As can be seen in the sequence of satellite images below, Moamba has grown in a fast and unplanned way. Its location, on the intersection of the National Road Nº4 and the railroad that links Mozambique and Republic of South Africa, makes Moamba village a corridor of persons and goods; which has been considered as one main structural factor in its process of demographic growth (Universidade Eduardo Mondlane; 2017). The testimony of people interviewed in my fieldwork points out as another explanatory factor of this process, a

circumstantial one though, the civil war that ravaged Mozambique between 1976 and 1992, which led to a first migratory flow towards the town in the early 1980s.

The yellow line on figures2, 3 and 4 show the contrast between the planned parts of the village, which follows a grid design, with the unplanned parts, which does not follow any particular patterns.

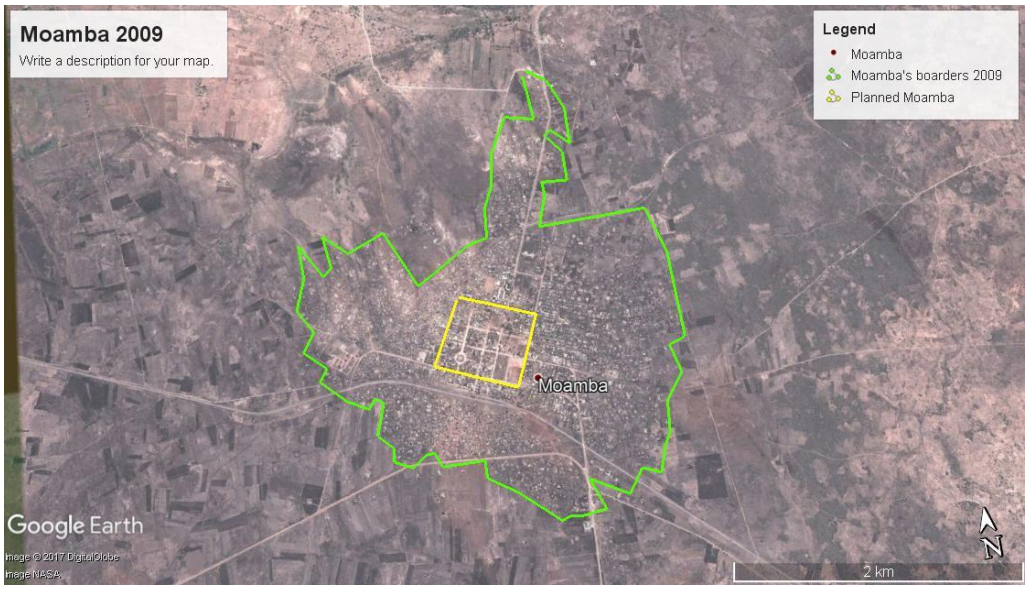

Figure 2: Village of Moamba at 2009

Figure 3: Planned and unplanned areas of Moamba

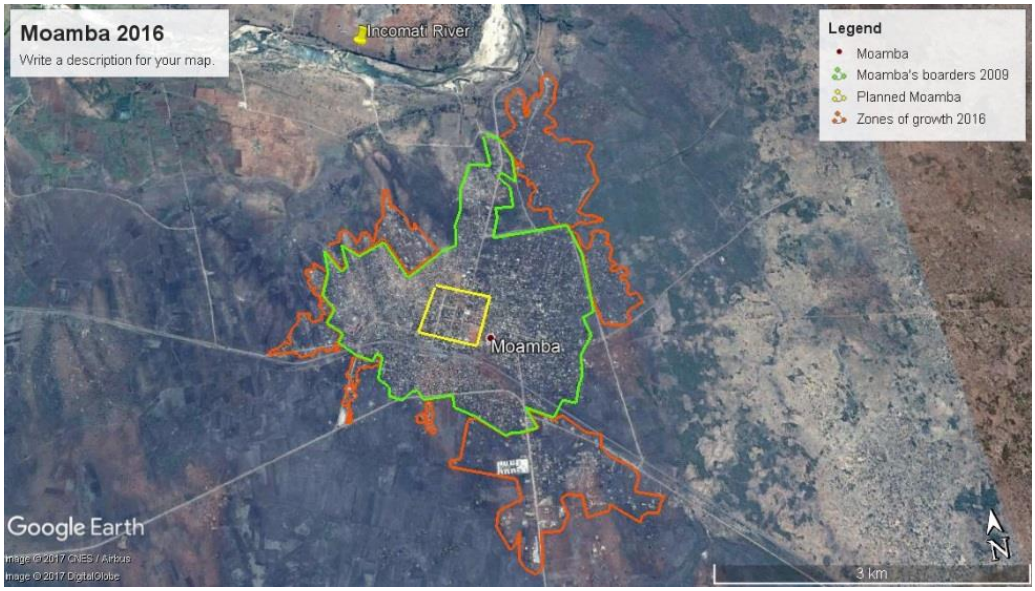

Figure 4: Moamba in 2016

I reconstructed Moamba's water supply system history mainly based on the testimony of IN41. He is an octogenarian man who has lived almost his entire life in the village, and worked as operator of the system since 1972 until 2010. He divided the evolution of this infrastructure in three phases (here phases 1 to 3)[2]. I triangulated and complement his testimony with the testimonies of his grandson (currently working as operator of the system), and the testimony of other users of the infrastructure. Based on this data triangulation, I identified two more phases: 4 and 5. In the present chapter I describe and analyse the main changes occurred in the layout, materiality, shape, and functioning of this water infrastructure in each one of these phases, which cover the period between 1962 and 2017.

4.1. Phase one: The colonial times (1962 - 1972)

The first phase began in 1962 when the colonial government installed the components of the first version of the Moamba's water distribution system. Namely, a steam-pump and a filter tank in the current location of the intake station; and from here an asbestos cement pipe of 125mm diameter and 3.8 km length to transport water from the Intake Station in Incomati River to two water storage tanks with an approximately capacity of $92m^3$ each. This water was used to fill the water tank of the train to provide with water to Administrative Post of Ressano García, the houses of the Portuguese members of the railway company (located next to the station) in Moamba; the bathroom next to the railway built for the passengers and staff members; and the standpipe in Bairro Indigena, where Mozambican workers of the railway company used to live (see the photographs and satellite picture below). The water was pumped three times per day, one hour every time (from 06:00 to 07:00; from 12:00 to 13:00; and from 17:00 to 18:00), and the water storage in two cement elevated tanks (see figure 5).

[2] Interviewed on 21.11.2017.

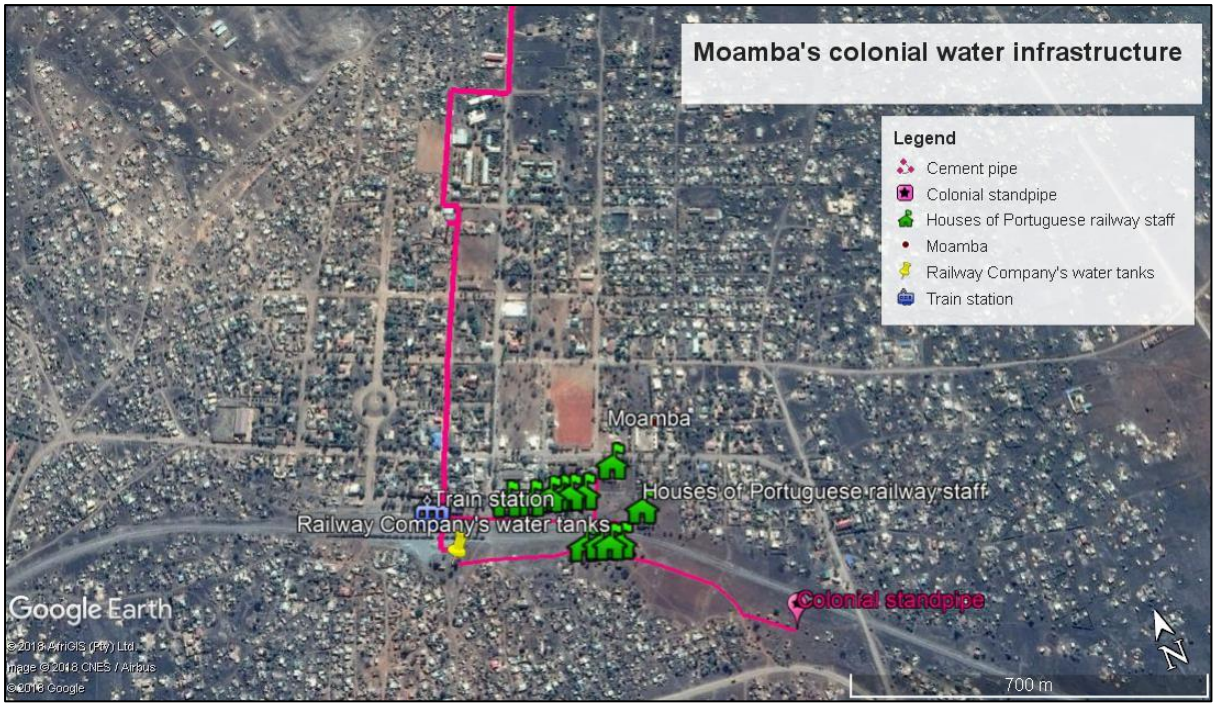

Figure 5: Moamba's colonial water infrastructure

Figure 6: In the left: Steam-pump. In the right: 125mm asbestos cement pipe

Figure 7: Old asbestos cement pipe near to Intake Station.

During colonial times, only Portuguese people had piped water connections in theirs houses. The staff members of the Railway Company, “the bosses”, used to live near to the train station (see the green houses in the satellite image above). The rest of residents of Moamba should ask water from them or take it from the only two public water taps existing in the town: one located behind the Energy Station (tap connected to the Colonial Railway Company’s water tanks), and another in the bathroom built next to the railway for the benefit of the passengers. Among the native population, those who decided not to fight the colonial government received some “privileges” such as the possibility of work in the Railway Company and send their child to school. These Mozambican were provided with cement small houses located in which is known as the “Bairro Indígena” (Indigenous neighbourhood), which forms part of Bairro Central. In this neighbourhood a stand pipe was built for the benefit of its residents (see picture below). When these water sources did not work, Moamba’s resident needed to take water directly from Incomati River. The water got from all these sources was for free and used for all the everyday activities, such as cooking, drinking, bathing, doing laundry and cleaning the house.

Figure 8: In the left side: Colonial Railway Company's water tanks. In the right: Colonial standpipe in Bairro Indígena

According to IN41 the origin of the town and its growth was the presence of the train station, the water infrastructure associated to it and the presence of the governmental institutions. The civil war, between 1975 and 1992, impulse a process of change in the settlement patterns in Mozambique, from a scattered one to a more concentrated one. In Moamba this process occurred since 1980 when people escaping from war started to look for a place to live inside the boarders of the town. It was in this decade when the war moved over the south of the country and Moamba offered two important things for the inhabitants in the region: presence of police and army troops of FRELIMIO, the government party; and water. In 1972 the colonial administration had built a Water Distribution Centre, where 4 water taps were installed. The people displaced by war tried to settle next to or near to the place where these water taps were installed and every day they queued to get water from here.

4.2. Phase two: The initial development of Moamba's water distribution network (1972 - 1989)

The second phase started in 1972, when the colonial administration built the water distribution centre in its current location and replace the section of asbestos cement pipe that used to bring water from the Incomati River to the distribution centre (the 3.1 km length) with a 110mm copolene pipe (see in green in figure 8). The colonial pipe that went from here to the Railway Company's water storage tanks and from here to Bairro Indígena, remained in use until the beginning of 1990s (in pink in the same image). The pump in the Intake Station also was replaced for a new one, however, IN41 say that the new one was also small and had not too much power. This time, the purpose of the water infrastructure was the allocation of water among Moamba's native residents, in contrast with the main purpose of the colonial water

infrastructure, which was to supply the Portuguese population and fill the water tank of the train to transport water to the Portuguese population of Administrative Post of Ressano García.

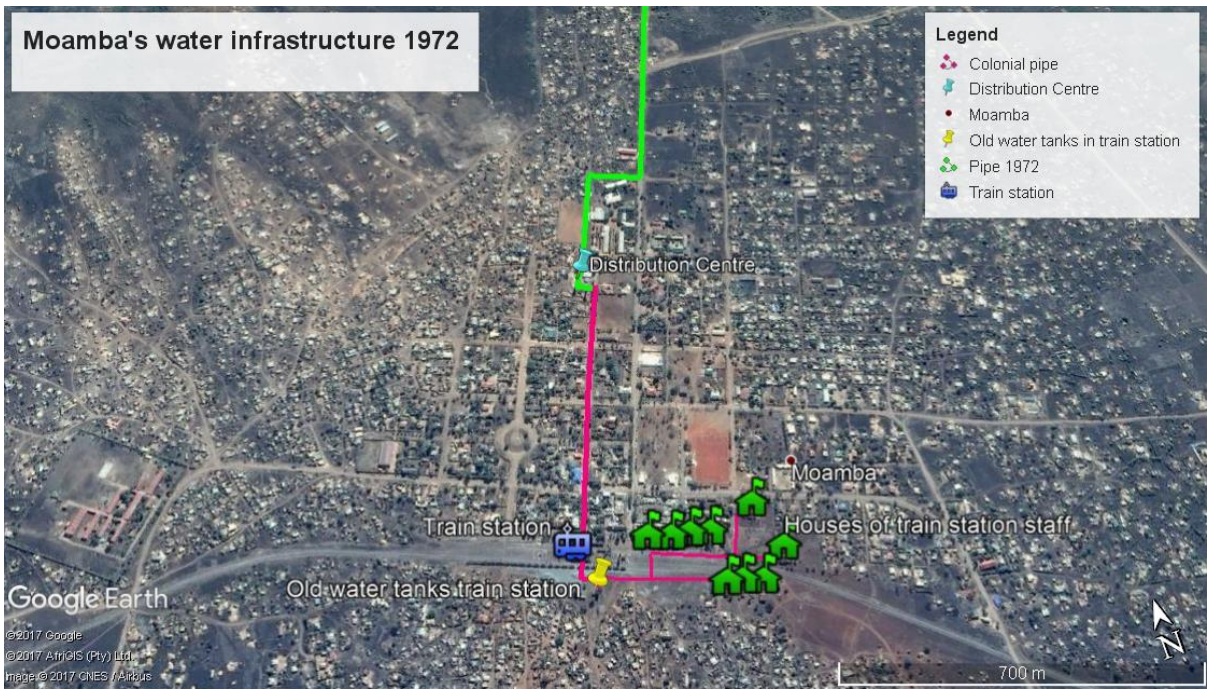

Figure 9: Moamba's water infrastructure 1972

This first Distribution Centre had a similar scheme that the currently in function. It was provided with a Water Treatment Station, where Sulphide Aluminium was injected into the water flow before it goes through six filters, and later injected with Chlorine for disinfection. From here the water went to a ground tank of 150m3 and from here pumped to an elevated tank with capacity to 80m3 (see figure 9 A). As I mentioned before, there also were 4 water taps, from where all people capable to reach the Distribution Centre by walking used to get water from without charging any money. The families with money started to request the installation of water connections in their houses (water taps in the yard). They started to pay monthly water bills based on their water consumption (the connections include water meters). The water allocation schedule keeps the colonial scheme (three times per day, one hour every time). It is important to keep in mind that since 1975 a civil war began and endures until 1992. This was an important factor for the slow development of the water network during this period.

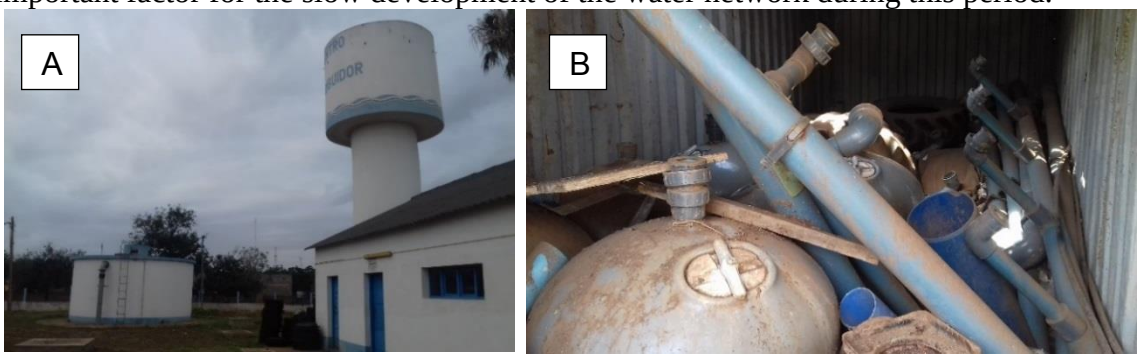

Figure 10: A: 150m^3 ground water storage tank and 80m^3 elevated tank. B: old filters storage next to old

4.3. Phase three: extending the network but reducing the water pressure (1989 - 2011)

The third phase began in 1989, when the government started to extend the water distribution network using pipes made on copolene. The section of colonial pipe that used to transport water from the Distribution Centre to the elevated tanks of the Railway Company were cancelled. IN41 does not remember exactly the years in which each section of the network was installed because the development of the network was progressive, but it is clear that it followed the grid of the streets in the planned area of Moamba, known as the "Bairro do Cimento" (Cement Neighbourhood). By 1999 the water distribution network looked as showed on figure 10. This image also shows that the extension to the network included the installation of standpipes, called *fontanarios* in Portuguese. The standpipes become the main water source for those households that cannot afford the installation of private connection or the monthly payment of water bills. On the other hand, the pipes installed to connect these fontanarios facilitates that people with regular incomes to install private water connections into their houses. People living far away from the standpipes used to buy water from the houses with private connections, just as occur today[3].

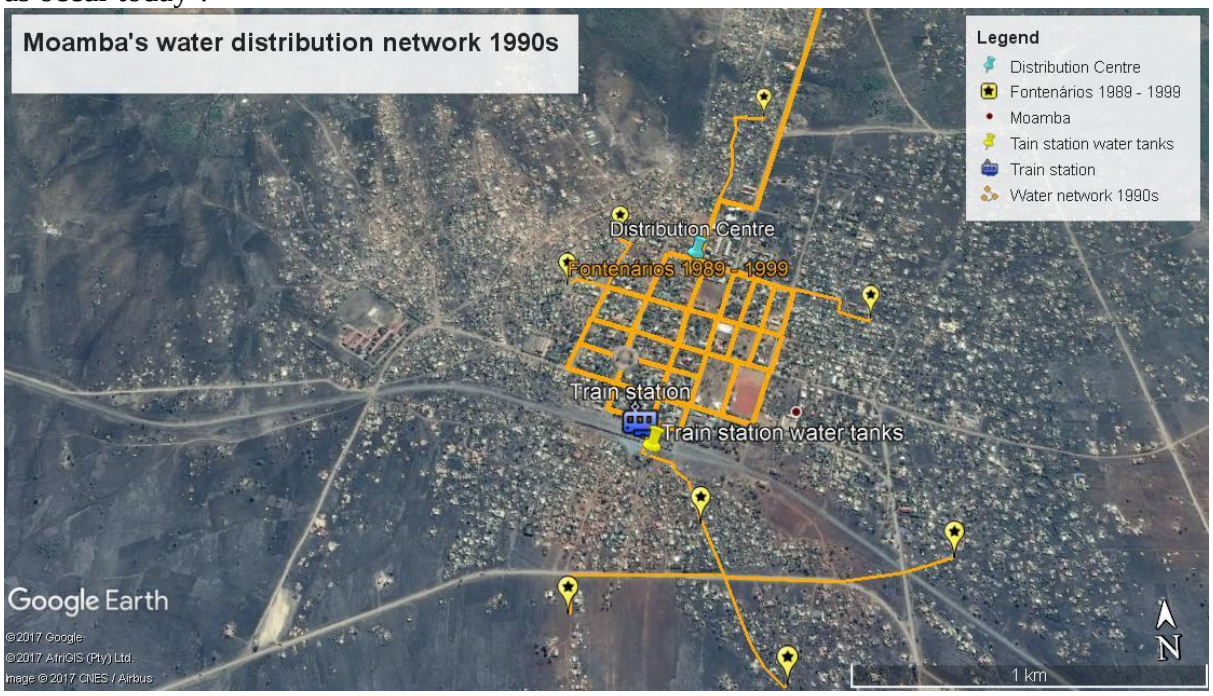

Figure 11: Moamba's water distribution network 1990s

By this time the pressure in the system was not enough to make the water goes up and fill the Railway Company elevated tanks. To solve the problem, an underground tank with a capacity of 75.79m3 was built, just in front of the elevated tanks and an electric pump were added to make the water reach the elevated tanks (see figure 11). From these tanks water was transported through a copolene pipe of 63mm diameter to the south-east, across Bairro Central, crossing

[3] Interview with Georgina and IN33 on Wednesday 8 of November 2017.

the road called “Estrada Velha” (old road), to finally enter into Bairro Sul. As the figure 11 shows, another pipe was installed in the axe east-west next to Estrada Velha, forming a cross.

Figure 12: Detail of underground tank and electric pump in front of the colonial tanks

According with the testimony of my interviewees[4], during the 1980s until 1998 the water sources of the residents of Bairro Central were the standpipes shown on figure 11 and two water taps: one installed behind the Power Station (see figure 12) located next to the elevated water tanks of the Railway Company, and the other in the public bathroom built for the train passengers next to the railway. People used to get water from the water taps two times per day: from 06:00 or 07:00 to 11:00 or 12:00 hrs, and from 18:00 - 20:00 hrs. The tap located behind the Power Station worked until 2001.

[4] Interview with IN4 on 14.12.17; with IN27 and IN15on 06.01.2018; with IN29 on 09.01.2018; with IN38 during an informal conversation on 23.11.17.

Figure 13: Moamba's power station during colonial times

In 1998 the local government built a well and installed a hand-standpipe in the place. According with the testimony of "IN40"[5], an elder woman that used to worked in the site of the standpipe charging customers and controlling the queue, "the well was [registered] on behalf of the Secretario do Bairro Centra"[6], but in total there were four people, called "Comisarios" (commissioners), involved in the administration of this well: the Secretario do Bairro; the manager of the well and two people responsible for charging the customers and bring the money to the Manager at the end of the month (one was IN40). Between 1998 and 2001 they used to charge 2MT per drum (20lt and 25lt). In 2001 the manager installed an electric pump and two elevated tanks, and replace the hand-standpipe by one with a tap (see figure 13). Then they started to charge 5MT per 20lt drum. The money was destined for reparations and maintenance. This well worked until 2016, when the pump and the water meter were stolen

[5] Interview on 14.01.2018.

[6] In Moamba the responsible of the district government is designated under the title of "Administrator". This person is designated by the Ministry of State Administration and Public Function and do not have a fixed period of government. In addition to this position, there are *Secretario do Bairro* (neighborhood secretary in direct translation), responsible of one neighbourhood; and *Chefe do Quarteirão* (Head of the Quarter), responsible for a group of house that could be 10 or more. People occupying these two position are elected and can be lifelong charges.

Figure 14: Old site of the Bairro Central well, standpipe and elevated tanks

In the water-tap located behind the Power Station the water was for free, but for much people this water-tap was far away from home and the amount of people there was big and the disorder in the queue was a common problem. In 2001 a private well was built approx. 200m away from the well administrated by the Bairro Central secretary. The price was the same but there used to be disorder in the queue and some of my interviewees did not come again to that well after suffer the robbery of their drums. So, with the pass of the time more and more people, most of them women, started to use the Bairro Central well as their main water source (see the location of this well on figure 14). Eventually the amount of people using this well also was big and users needed to go very early in the morning to start to do the line.

Different interviewees[7] coincide at saying that they needed to start the queue at 03:00 or 04:00 in the morning to have chance to fill their drums. Here the testimony of one interviewee about this practices: *"I used to go at midnight to "mark the line": I leave one of my 25lt drums marking my position in the queue, after which I went back to bed until 03:00 hrs. At that time I went back to the well and stay there until 06:00 hrs, hour in which the well opens. Then we had to wait. Sometimes you could fill your drums soon, but other days the clock marked 12:00 hrs and we were still there. At that time the well closes to re-open at 14:00 hrs. If by that hour you did not be able to fill your drums, you possible will be going back home at 15:00 or 16:00 hrs."* (IN27, interview on Saturday, 06.01.2018).

The power of water infrastructure to shape the routine of people in Moamba is a point that I analyse more deeply on chapter 7. However I will highlight here that this quotation shows how water infrastructure have a different impact on the everyday life of people depending on the type of infrastructure used (private in-home water connections or public standpipes) and depending on the gender of the water user (fetching water is a female activity in Moamba). If

[7] Interviews with IN4, IN27, and IN29.

you were a woman without water-tap at home living in Moamba in this period, that means that you should spend several hours per day every few days at the standpipe trying to get enough water for your family. There was no guarantee that people would get the amount of water they was requiring, which also had consequences in terms of their water security. On the other hand, women had less available time to engage with other activities.

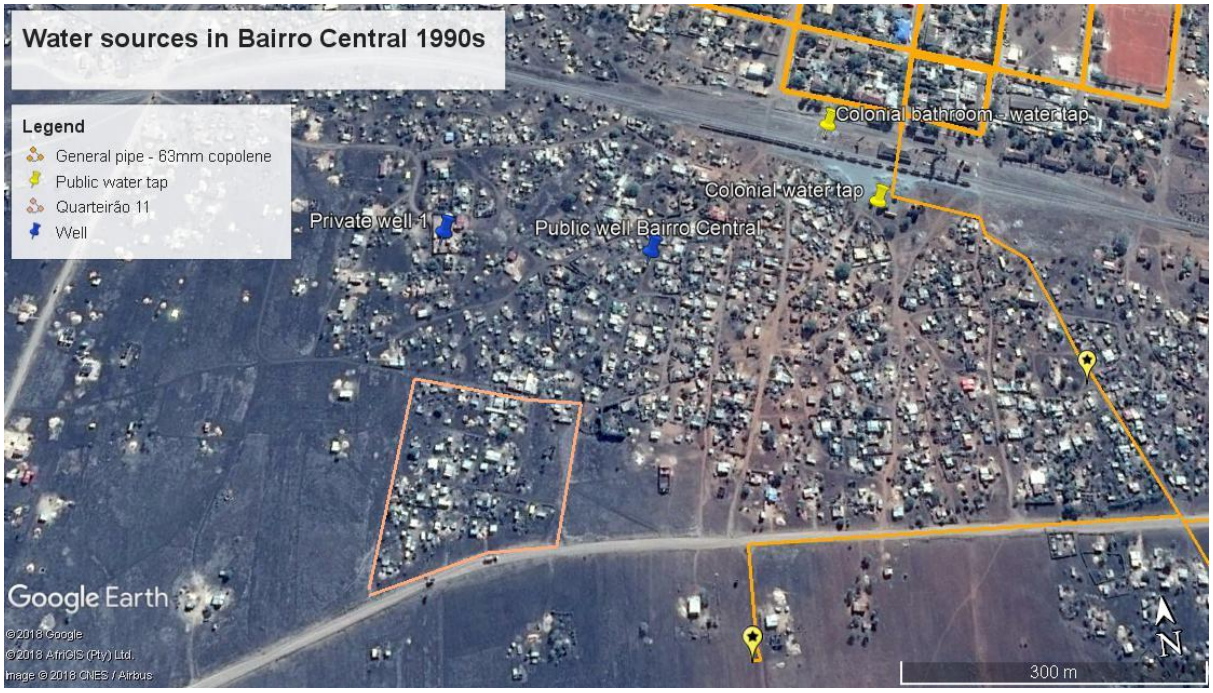

Figure 15: Water sources in Bairro Central during 1990s

According to IN33and IN41, the extension of the water distribution network and the consequent increment in the number of household connections brought a reduction in the water pressure in the system and progressively the areas far away from the Bairro do Cimento started to run dry. By 2000 the majority of standpipes were dry (see in the standpipes circled in red in figure 15) [8].

[8] Information provided by IN41 on November 21, 2017 and one of his grandsons that is currently operator of the system and resident of Moamba since 1992. During this period the Distribution Centre only had one elevated tank in a tower of 19m from where the water was distributed to the network by gravity. Today the mechanism is the same but there is a 2013 second tower higher than the previous one, currently in use.

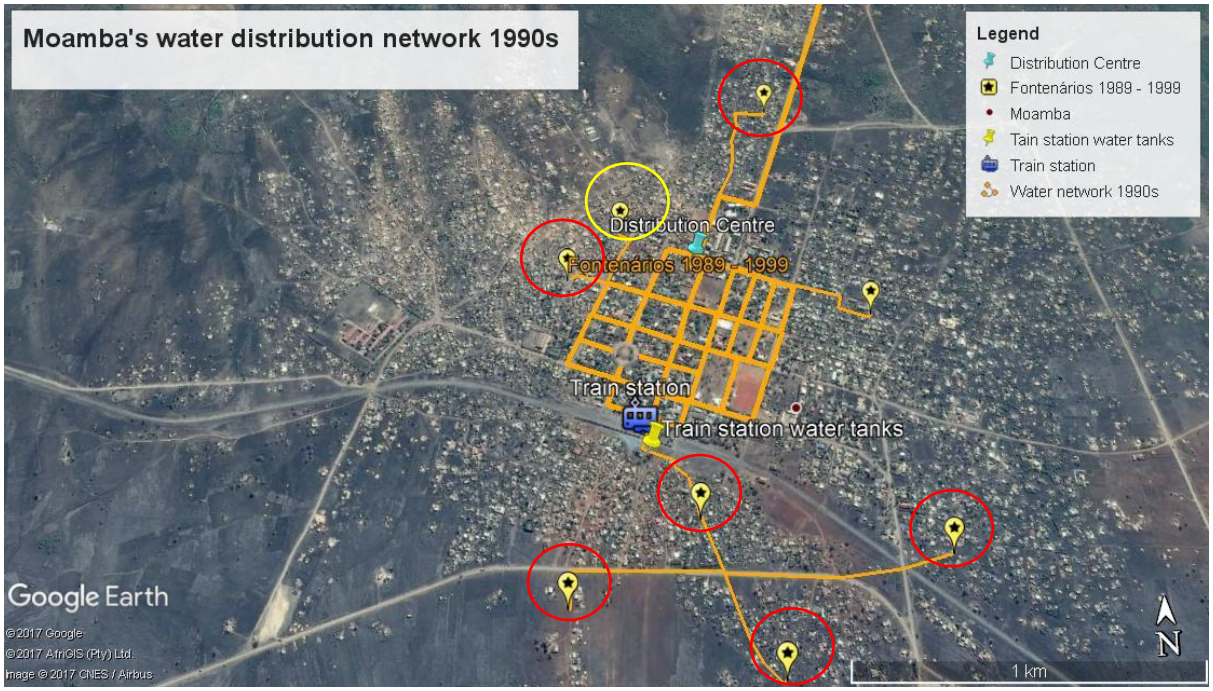

Figure 16: Standpipes that run dry by 2000

In response to this situation of water scarcity some people built tanks to storage water in their yards (see figure 16). The construction of water tanks implies the availability of money. The families with water tanks I observed have in common that all of them has, or has had at least for a while, one of its members employed. During the 90s the existence of these tanks gave the owners the opportunity to re-sell water and this had implications for the social relations of the families. In words of one of my interviewees: "*Before the tank nobody knows me in the village. But after the tank when I walk around people started to greet me. When a house had a tank it become known in the town*". This kind of relation have the potential to increase the social network of households and individuals, network that could be used as a network support in case of need.

Figure 17: Water storage tanks

In 2005 a new Administrator (person in charge of the district government) arrived to Moamba. His name is Tefula and he is remembered in Bairro Central for be the man who put again in function the colonial water tanks property of the Railway Company, for renewed the standpipes and install some more, and for extend the water distribution network in this neighbourhood.

Figure 17 show in purple the pipes Tefula renewed and extend. Circle in red appears the two standpipes he installed, and in fuchsia the colonial asbestos cement pipe that, according with the testimony of one resident of Bairro Indigena[9], was in function during this period.

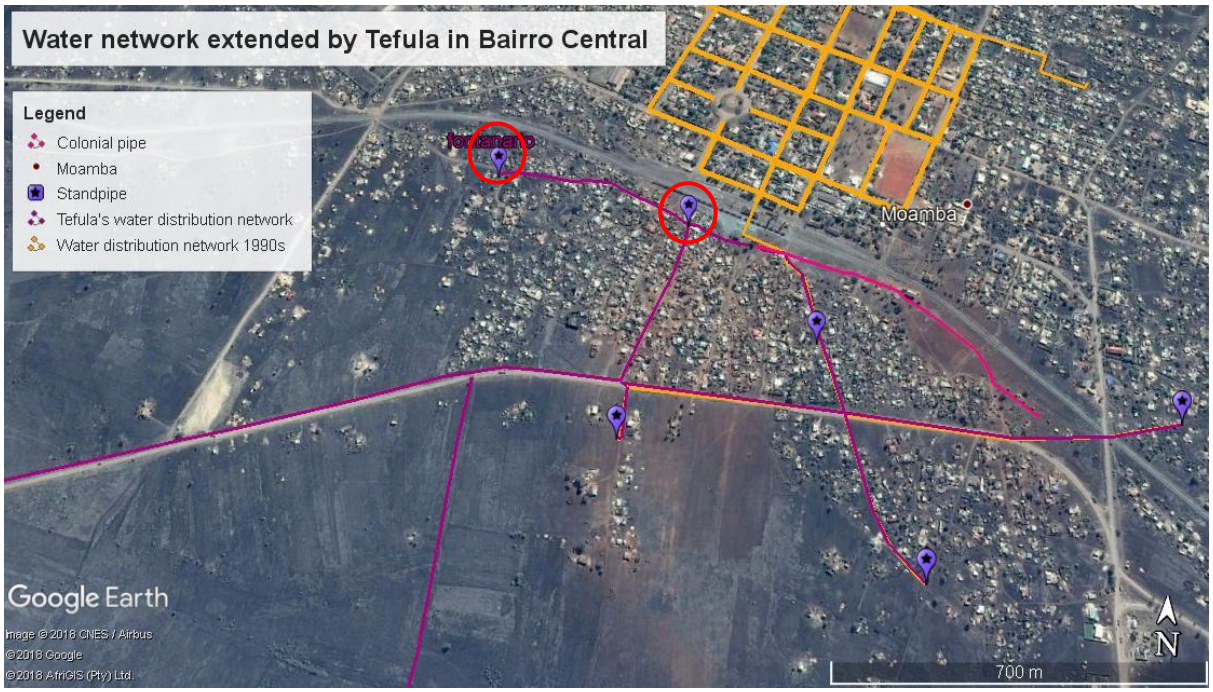

Figure 18: Water network extended by Administrator Tefula in Bairro Central

The pipes used to extend the network were made on the same material used during the 1990s: copolene pipes of 63mm diameter. Unfortunately the pipes installed by Tefula in Bairro Central were in function not for too long. According with the testimony of the members of one household in Quarteirão 4, as part of the extension of the network the administration installed a pipe in their street. They connected to this pipe a 25mm copolene pipe that allowed them to have water inside the house. The water flowed from 2007 until 2009. When the water flow stopped this family started to buy water in the underground water tank in front of the elevated colonial tanks. They used this tank until 2010 when this tank went dry and they went back to buy water from the Bairro Central well.

4.4. Phase four: The privatization of the system (2011 - 2014)

The construction process of the current water distribution network of Moamba, inaugurated in June 2013, mark the beginning of the fourth phase. However the first stages of this project started in 2004 as part of the new national government policy of delegate the operation of the water infrastructure in small towns to the private sector. This project consisted in the rehabilitation and extension of the potable water supply system. The National Water Direction, Department of Rural Water, contract with a private consultancy called Tecnica. Engnheiros

[9] IN43 is an ex-employee of the colonial railway company. He was interviewed on 04.01.2018.

Consultores, LDA to design the new water treatment and distribution system. The current general manager of Collins, the water utility that provide potable water to Moamba, worked in this project as the general coordinator. His role was to ensure that the design respond to the ToR[10]. According with him the stages of design and budgeting took from 2004 to 2010. The construction begun in 2011 and finished in 2013, having in the end 29 standpipes in function (see figure 18). The construction works were overcome by another company called Conduril. The duration of the construction process was confirmed by two people employed in this project as builders[11]. Two events coincide with the decision to rehabilitate and extend the water supply network in Moamba: the running dry of the standpipes and the outbreak of cholera that took several lives between the 1999 and 2003[12]. Foreseeing the growing of the population in Moamba, the government request the consultancy a water network design to have a useful life of 25 years.

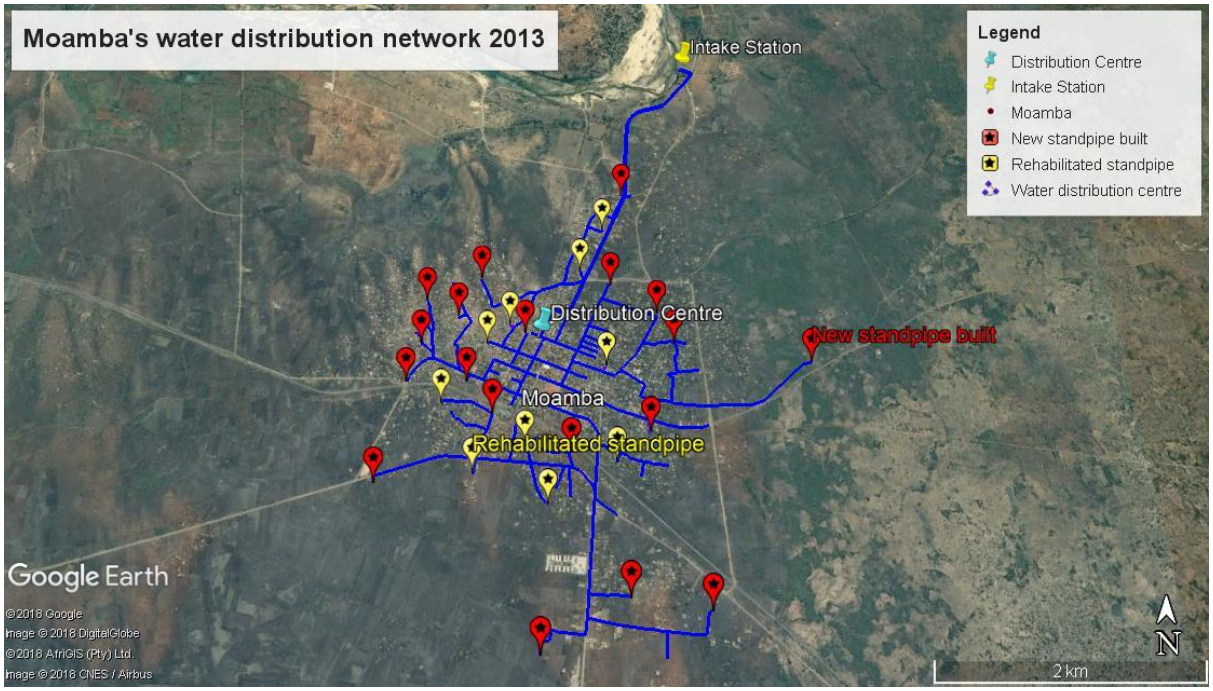

Figure 19: Moamba's water distribution network in 2013

During the construction period the water distribution service was stopped. People had to start buying water from particular cars that take water from the Incomati River to sell it at 15MT per 20lt, three times more than people used to pay today. These were very difficult times for residents of Moamba. One of the interviewees[13] said that during this period her household (composed then by four members) used to buy 1000 lt (1m3) every 5 days. This situation forced them to reduce their water consumption to the minimum, reducing the number of showers and the frequency of doing laundry during the week. They also lose the money that they used to get from re-selling water from their tank, money used to buy bread and breakfast. They were no able to produce cement breaks to expand their house neither during this period.

[10] Interview with PC on Thursday 2 of November 2017.
[11] Interview on 05.01.2018.
[12] Interviews with IN 4 and IN5 on 14.12.17 and IN39 on 08.11.2017.
[13] IN39 and IN33 on 08.11.2017

In June 2013 the extended and rehabilitated network began to be operated by Collins. From September Collins started to install new private connections as customers requested. According with Collins' general manager, the increment of private connections made obsolete the standpipes very soon, because there were no people interested in buying water from standpipes anymore. This was the explanation he gave me for the cancellation of the standpipes in the beginning of 2015. The cancelation of the standpipes was also part of a change in public policies. As I said before, the national government chose to delegate the administration of water infrastructure in small towns to the private sector, which is also related with a more general change in the economic policy of Mozambique, now oriented to promote the development of the private sector in the country. From now on, the provision of potable water service in Moamba should generate revenues. Additionally, Collins' general manager also recognize[14] that the task of controlling the standpipes was a very difficult one, because the water meter lectures were not accurate and people hired to charge customers for the water did not report all the money made during the month: "The numbers did not fit", he said. Also, as he mentioned in other interview[15], the current priority of Collins is to increase the number of private connections, which seems to be in contradiction with the existence of public standpipes.

4.5. Phase five: the installation of second-hand pipes to extend the distribution network (2014 - current)

We can consider 2014 as the beginning of a fifth stage in the evolution of Moamba's water distribution system. In different moments of this year some neighbours organized themselves to make extensions in the water distribution network, installing by themselves pipes in their areas of residence, areas that did not were covered by the construction project overcome by Conduril and that will not be covered by Collins in a short or middle term. The figure 19 shows seven of these pipes in sky-blue. In some cases the neighbours bought new pipes and in others, as in Bairro Central, the neighbours choose to unearth and re-use the copolene pipes of 63mm diameter installed during the government of Tefula, not in used anymore by that time. When the unearthed pipes were collocated in its new place, Collins sent a technician to connect these pipes to the main water distribution network. The satellite image below show how Moamba's water distribution network looks today.

[14] Interview on 31.01.2018.

[15] Interview on November 17, 2017.

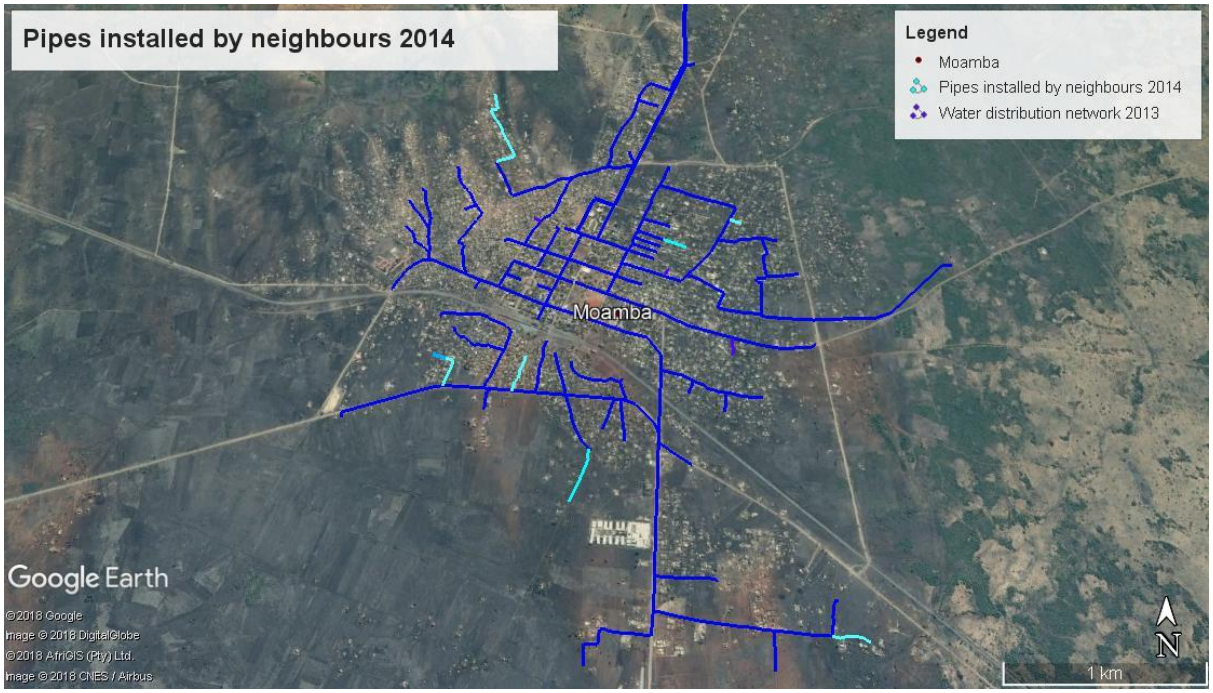

Figure 20: Pipes installed by the neighbourhoods in 2014

The current water supply system is composed by five general components: an intake station in Incomati River; a small water treatment station; a water distribution centre; abductor conducts that transport water from the intake station to the treatment station; and the water distribution network. Additionally, from the water distribution network the water is transport towards the Administrative Post of Pessene, 14km away from Moamba, and from there to the settlements of Tenga 9km away from Pessene.

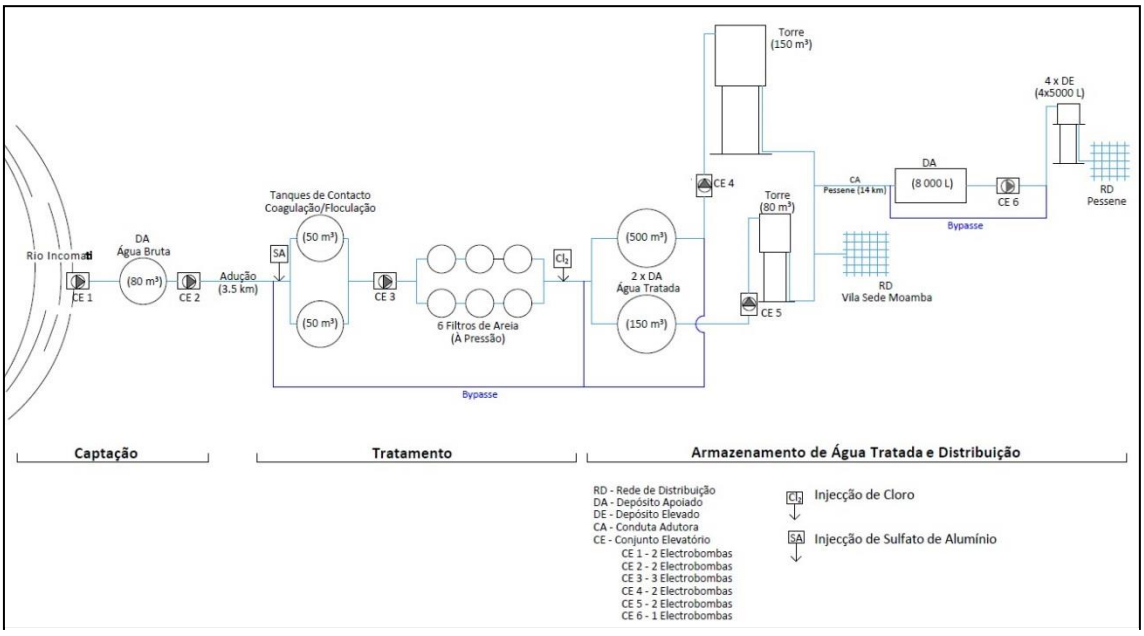

Figure 21: Moamba's Water Supply System Scheme

Source: “Plano de Segurança da Água. Módulo 2 - Descrição do Sistema de Abastecimento de Água. ETA da Moamba – Distribuição em baixa na Vila Sede de Moamba”

Figure 22: A: local water catchment in the river Incomáti; B: buffer tank; C: building of surface bombs; D: surface pumps.

Figure 23: A: 500 m³ groundtank and 150 m³ pressure tower; B: 150 m³ groundtank and 80 m³ pressure tower.

According to the Water Safety Plan of Moamba, this infrastructure was inaugurated on June 2013 to operate in a concession area of ten neighbourhoods with a population of approximately

24,650 inhabitants. The original coverage projected was of 45%. According to Collins' general manager[16], the current coverage provided by the water utility company is 56%. As the chart below shows, in Moamba village the water infrastructure supply seven neighbourhoods, and within these neighbourhoods exists 2,503 domestic and public services connections; four schools and one hospital.

Table 2: Number and type of connections by neighbourhoods

Neighborhoods	Type of Connections	Number of Connections
Madinguine	Domestics and Public Services	367
Matadouro		581
Cimento		305
25 de Junho		180
Central		382
Sul		291
Livivine		397
Pessene		195
Tenga		2
Mahoche		65
Maguaza		38
Madinguine	Schools	1
Matadouro		1
Cimento		2
Cimento	Hospitals	1
Pessene	Fountains	2
Tenga		2
Maguaza		1
SUM		**2813**

Source: Collins. Sistema de águas Ida.

[16] Interview on 06.11.2017.

Table 3: Changes in Moamba's water supply system 1962 - 2017

	Phase				
Characteristics of water system	I 1962 - 1972	II 1972 - 1989	III 1989 - 2011	IV 2011 - 2014	V 2014 - nowadays
Components	1. Steam-pump Intake Station	1. Electric (?) pump Intake Station	Electric pump in Intake	1. Intake Station: - collection well and infiltration chamber - two submersible pumps 160m3/h - two electric pumps 314m2/h	
	2. Filter tank Intake Station	2. Main pipe: '- intake-Distribution Centre 3.1km length; Distribution Centre-train station 0.7km length. - Material: copolene - Diameter: 110mm	2. Main pipe: - intake-Distribution Centre 3.1km length; Distribution Centre-train station 0.7km length. - Material: copolene - Diameter: 110mm	2. Main pipe: - intake-Distribution Centre 3.1km length; Distribution Centre-train station 0.7km length. - Material: PVC - Diameter: 250 mm (PN9)	

	3. Main pipe Intake-train station: '- 3.8km length - material: asbestos-cement - diameter: 125mm	3. Treatment Station: sedimentation tank and filters.	3. Treatment Station: sedimentation tank and filters.	3. Treatment Station: - Two 50m3 sedimentation tanks - Aluminium sulphite e Hipoclorito de Cálcio Ca(ClO)2 injector - Six filters (45 m³/h) - Three electric pumps (capacity 80 m³/h). - Clorine injector	
	4. Two water storage tanks (train station). - capacity: 92.49m3 diameter 5.68m Height: 3.65m	4. Distribution Centre: 150 m³ ground tank; pressure tower 80m³.	4. Distribution Centre: 150 m³ ground tank; pressure tower.	4. Distribution Centre: - two treated water storage tanks of 500m³ and 150m³. - Four electric pumps: two each one of the two pressure towers - Two pressure towers: one of 150 m³ and the other of 80 m³.	
	5. Distribution network to colonial houses and Bairro Indigena standpipe.	5. Two water storage tanks (train station).	5. Three water storage tanks (train station).	5. Water distribution network	Extensions made by the neighbours.
	6. Stand pipe in Bairro Indigena	6. Distribution network to colonial houses and Bairro Indigena standpipe.	6. Water distribution network	6. Stand pipes (29).	Standpipes canceled.

		7. Eight standpipes : - Madinguine: 1 - 25 de Junho: 1 - Matadouro: 2 - Livivini: 1 - Central: 2	7. Ten stand pipes: - Madinguine: 2 - 25 de Junho: 1 - Matadouro: 2 - Livivini: 1 - Central: 4	7. Inhouse connections.	
Lenght main pipe and distribution network	5.08 km	5.08 km	13.14	32.94	36.69

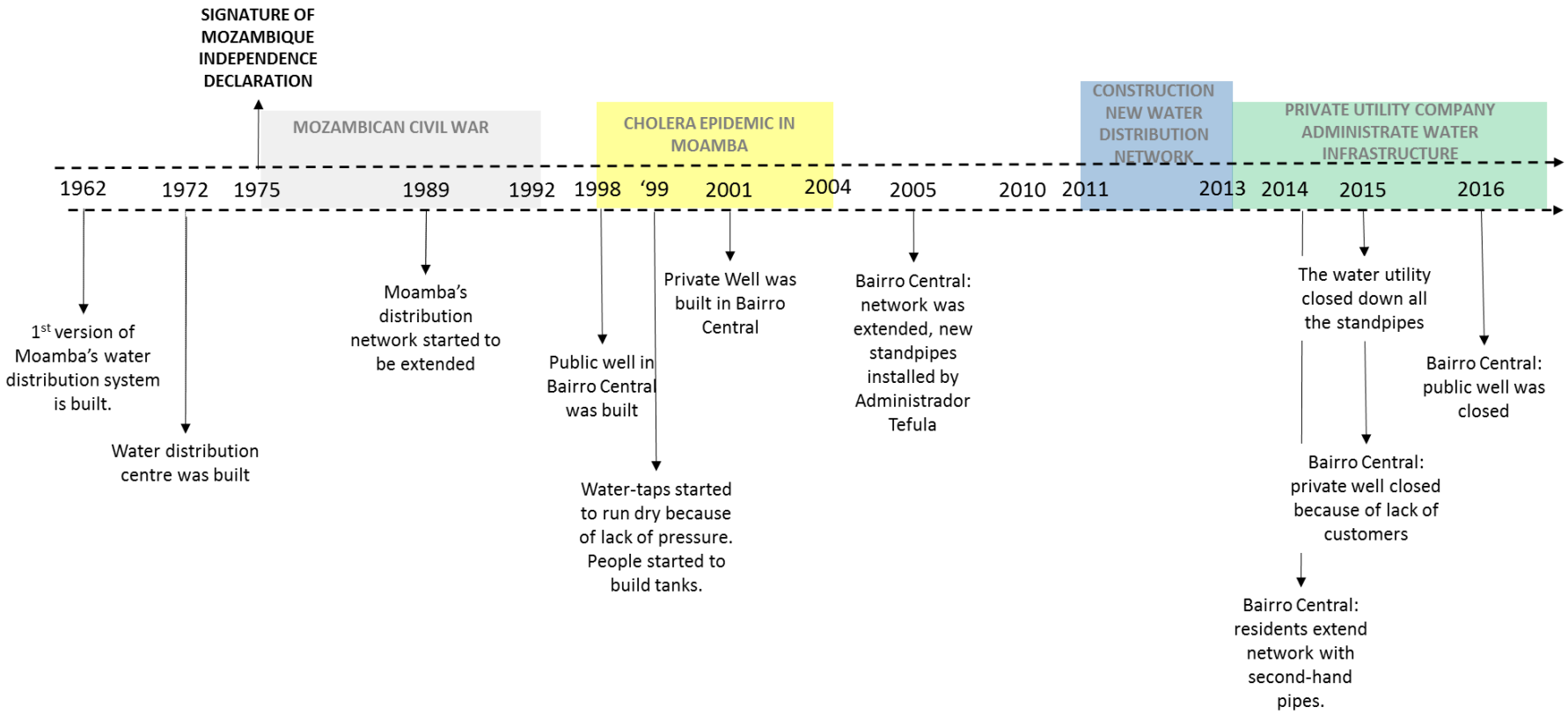

Figure 24: Time-line. Moamba's water infrastructure

4.6. The political dimension of water infrastructure

The reconstruction of the evolution of Moamba's water infrastructure presented above, shows that the main changes in Moamba's water infrastructure occurred in its layout; in the extension and materiality of the distribution network; in the diameter and capacity of the main pipe; and in the number and complexity of the components added to the system. It is not possible to isolate these changes from the general technical evolution (such as the passage from the steam-pump to an electric one) and the development of the technical system with which the water infrastructure interact such the national power grid. However, I argue here that the change in the functioning of the water infrastructure and its increasing complexity are linked to political processes involved in the historical passage from being a Portuguese colony, to be an independent country with a communist government, and more recently, the implementation of neoliberal policies, among which we find the promotion of the private sector in the administration of the rural water infrastructure in Mozambique.

During colonial times, water infrastructure was used as part of a mechanism of racial segregation to reinforce and reproduce the Portuguese domination. To summarize this point, the colonial water infrastructure was aimed at supplying with water to the relatively small number of Portuguese citizens in Moamba through in-house piped connections, while only a small sector of the native population had the privilege of accessing piped water through one public standpipe installed in Bairro Indígena. This neighbourhood was built to provide with the housing to the Mozambican workers of the colonial railway company, people that decided not to fight the Portuguese occupation. In words of the secretary of Bairro Central: *"they decided to be assimilated into the colonial society and because of this, they were rewarded. They could have access to a job and send their kids to school. These houses were built for them"*[17]. In this way, water infrastructure not only served to implement a differentiated hydraulic citizenship (Anand, 2011) for Portuguese and Mozambican people, but also created two classes or categories of Mozambican citizens: those who accepted the colonial government could have access not only to piped water and jobs but other benefits such as sending their kids to school. Those who resist to being assimilated to the colonial regime should remain in precarious living conditions.

With the independence of the country, the new purpose of water infrastructure was to provide drinking water to Moamba's residents, making, in theory, no distinctions. The users went from depending on the Portuguese government to rely on the national and district government, to whom they had to pay monthly based on their water consumption. This new purpose to provide drinking water to all Mozambican citizens implied the need for increasing and improving the capacity to treat water and to increase the amount of the water distributed. In concordance with this purpose, we see since phase 3, an important effort from the government to bring the water distribution network to all the neighbourhoods in Moamba. During this period the water distribution network was extended from approximately 5km of pipes to 13.Km. Two big limitations stand out from the way the water network was developed during this period: one is the persistence of a spatial differentiation in the provision of drinking water. The extension of the network occurred predominantly in the planned area of Moamba, corresponding to Bairro Cimento (cement neighbourhood) and, to a lesser extent, Bairro 25 de Junho, where an attempt

[17] Interview on 04.01.2018.

was made to reproduce the grid pattern design of the former. The second limitation was that each extension in the water distribution network led to an increase in the number of water users, which was followed shortly by a reduction in water pressure in the system. This, in turn, led the pipes eventually running dry.

The fourth phase is characterized by a change in the strategy of the Mozambican government By giving in concession the administration of the water infrastructure to the private sector, the government aims to improve the efficiency of the water supply system by creating financial sustainability. In consequence, the water network has been extended and the reliability of the system improved. However, these changes have not meant water for everyone. The problem is not just that the water distribution network does not reach all neighbourhoods (the coverage in Moamba is 56%[18]); it is also the fact that the quality of the service is not the same for all. In other words, water infrastructure is still a factor for the reproduction of social inequity in Moamba. Nevertheless, currently the (re)production of inequities in accessing piped water is more subtle because instead of being based on a racial segregation system imposed by a colonial government, it is conceptualized in terms of the economic situation of individuals and families: in theory all inhabitants of Moamba have the same right to access piped water, but in practice the water supply service is provided by a private utility company aimed at achieving financial sustainability and making profits. In consequence, the access to piped water is conditioned by the capacity of each family to afford a private connection and to pay the monthly water bill.

It is not by chance that the poorest zones in Moamba are also the areas with the worse water supply service. It is a vicious circle: its residents cannot afford to move to areas with better services and the utility company is not interested in improving the service, or expanding the network[19]. This is the case of Bairro Central, where a significant portion of its inhabitants do not have a tap at home, and those who can afford a private connection have a service characterized by cuts that last longer than in the rest of the neighbourhoods, and recurrent problems with the pressure. The finding of the persistence of this spatially differentiated access to water in Moamba resembles what Kooy and Bakker found when researching about colonial and contemporary water supply infrastructure in Jakarta: *"… contested and evolving process of social differentiation are linked to the differentiation of water supply infrastructures and of urban spaces*" (Kooy and Bakker; 2008: p. 1843).

The revision of Moamba's water infrastructure evolution has allowed identifying that water infrastructure also has repercussion on the politics of everyday life. When inquiring about the reasons that led to the closure of the public standpipes, the importance that the appropriation of these water sources had for the people who work at these points as money collectors and the users stands out, revealing standpipes as "wellsprings of power" (Meehan; 2014). The original project commissioned by the National Water Direction to rehabilitate and extend Moamba's distribution network contemplates the increment in the number of public standpipes from 10 to

[18] Interview with Pedro Cardoso on 06.11.2017.

[19] When asking to the interviewees why they decided to install a second-hand pipes in Quarteirão 11 all coincide in saying that the utility company deny their request to extend the distribution network arguing that the company did not has the resources. On the other hand, when discussing the alternatives to improve the water supply service in Bairro Central, Collins' general manager said they know how to solve the problem, but they do not make the required investment because their priority right now is to increase the number of private connections in Moamba.

29, and this design was respected in the construction. However, less than two years later of inaugurating the new network the water utility company decided to close down all the standpipes. I could identify three different narratives to justify this decision[20]. One is that standpipes become an unintended source of power for particular actors, the standpipes money collectors, making the utility company unable to exert a total control over the profits produced from the water sells in these points. Collins' general manager said that the difficulty in controlling the income produced in each standpipe was that the money collectors did not even need to manipulate or modify the standpipes' water meters in order to steal money because the readings of these gauges were not accurate[21].

This idea of standpipes as wellsprings of power was reinforced in me at seeing the surprise of one of the operators of the system when we discovered that the standpipe in Bairro Indígena was still working; despite the order given by the top management of Collins to close each and every one of them. It would be very difficult to determine with certainty whether it was a deliberate omission or rather a negligence that went unnoticed. What is evident, and interesting in terms of appropriation of water infrastructure, is that this standpipe was in use at that moment (a small farm was conveniently opened around the standpipe) and that the residents of Bairro Indígena were interested in keep this information hidden from the water utility company. It is possible to say that water users in Bairro Indígena found in the appropriation of this particular standpipe a way to fight the control that Collins looks to exert on the water infrastructure, and by doing so, contesting also the new neoliberal paradigm promote in Mozambique according to which the access to drinking water is conditioned by the fact of being a responsible citizen that pay punctually all his/her water bills.

According to a second narrative, also given by Collins' general manager, the standpipes were closed because of the increment of in-home private connections which left public standpipes without clients. However, other empirical data show that standpipes' customers had not completely disappeared. For instance, even current Chefe do Quartirão 11 is interested in install a well and standpipe in his neighbourhood to use it as a buffer against prolonged interruptions in the water distribution service. Of course, he can be also interested in using the standpipe as a personal source of income, but it shows that there are still potential users for this type of infrastructure. There are also several people that cannot afford the materials to install a water-tap at home. As consequence, they need to buy water from their neighbours, which according to the testimony of some residents of Quartirão 11, is an uncomfortable situation since it can be felt as a relationship of subordination that affects other dimensions of social interactions as well[22]. In this sense, and given that the increment of private connections directly benefits the private utility company, it could also been interpreted that the closure of the standpipes was a measure implemented to encourage the increase in the number of in-home water-taps.

The third narrative that could explain the closure of the standpipes is associated with the wider political process occurred in Mozambique in recent years. When the Water and Sanitation Infrastructure Administration (AIAs in Portuguese) gave the administration of the Moamba's water infrastructure in a five-year concession to Collins, it did it as part of a new strategy called "delegated management". This strategy looks to promote the autonomy, efficiency and financial

[20] See chapter five.
[21] Interview with Pedro Cardoso on 31.01.2018.
[22] Interview with IN29 on 15.01.18; and IN21 on 09.01.18.

viability of the secondary public water distribution systems by delegating its administration to private operators.[23] And this strategy is part of a more general policy that promotes the development of the private sector in the country. Public standpipes are very compatible with the political tradition of communism in Mozambique, but it is contradicting with the neoliberal policies promoted by the government and incompatible with the goal of the private utility company of increasing its profits.

4.7. How the water supply system is operated: prescribed versus actual practices

Every day by the action of opening and closing a series of valves, making pumps work, and additioning Aluminium Sulphide and Chlorine, the operators "disinfect" the water and make it flows through the village of Moamba. The process starts at 5:30hrs. Following the water supply system scheme, at this time the water should start flowing from the intake station to the treatment station, where the water is first injected with Aluminium Sulphide; then the water goes to two decantation tanks. From here it flows through six filters; then Chlorine is injected into the pipe that transport the water towards a 500 m^3 ground tank where the treated water is storage just before to be sent up to the pressure tower. From here the water is sent by gravity to the water distribution network.

However, the order in which the valves and the pumps are operated goes in the opposite direction: from the distribution centre to the intake station. Around 5:30 hrs one of the pressure tower pumps is put to work. This pump transport treated water from the ground tank up to the $80m^3$ tank located at the top of the tower. Ten minutes later, the operator put into work the Chlorine injector and turn-on two of the three pumps that propel water through the six filters. When the water level in the sedimentation tanks drops down, the operator called the person in charge of the intake station, to ask him turn-on the pumps that send the raw water to the treatment station, and turn-on the Aluminium Sulphide injector. Ten more minutes after the water turbidity in the pressure tower is measured (see figure 24)[24]. At 06:00hrs o'clock the

[23] See official webmail of AIAs, http://www.aias.gov.mz/index.php/quem-somos.

[24] The optimum values according to with IN36 is between 0 and 5MTU.

operator should open the valve towards the Water Distribution Network of Moamba, located next to the Pressure Tower (see picture).

After this, he has to control the water level in the sedimentation tanks. It should not surpass the

Figure 25: From left to right: water turbidity meter device. Operator opening the Moamba's water distribution network valve. Operator water level in the sedimentation tank.

hole in the tank's wall made to allow the tank "breath" (see picture). As soon the water reach this level the operator must call the operator in the intake station and ask him to turn-off the pumps there.

A variation in the way the water treatment station and the distribution centre are operated consist of using a bypass. By closing a valve the raw water coming from the intake station is deviated from its usual path towards the decantation tanks and redirected to the 500m^3 ground tank in which treated water is usually stored. By doing this, the operators skip the decantation, filtration and disinfection processes, the reason why according to the explanations of Collins' general manager and the operators of the system[25], this is an emergency measure reserved to the context of prolonged cuts in the water distribution service. When the system is restarted, it is necessary to refill the pipes in the distribution network in order to recover the water pressure needed to convey water to all the neighbourhoods in the village. Since the population has been suffering from a prolonged water shortage, the use of the bypass is aimed at saturating the distribution network in the shorter possible time. The problem is, Collins' general manager said, there is an error in the design of this bypass. Instead of redirecting the raw water to the ground tank, it should redirect it to the section of the pipe where the chlorine is injected (the red circle in figure 25 points out this detail). However, since the bypass redirects water to the ground tank, the operator needs to add the chlorine manually and discretionally.

[25] Interview with Collins' general manager on 13.01.2018 and explanations collected from the operators of the system during non-participant observations conducted during November 2017.

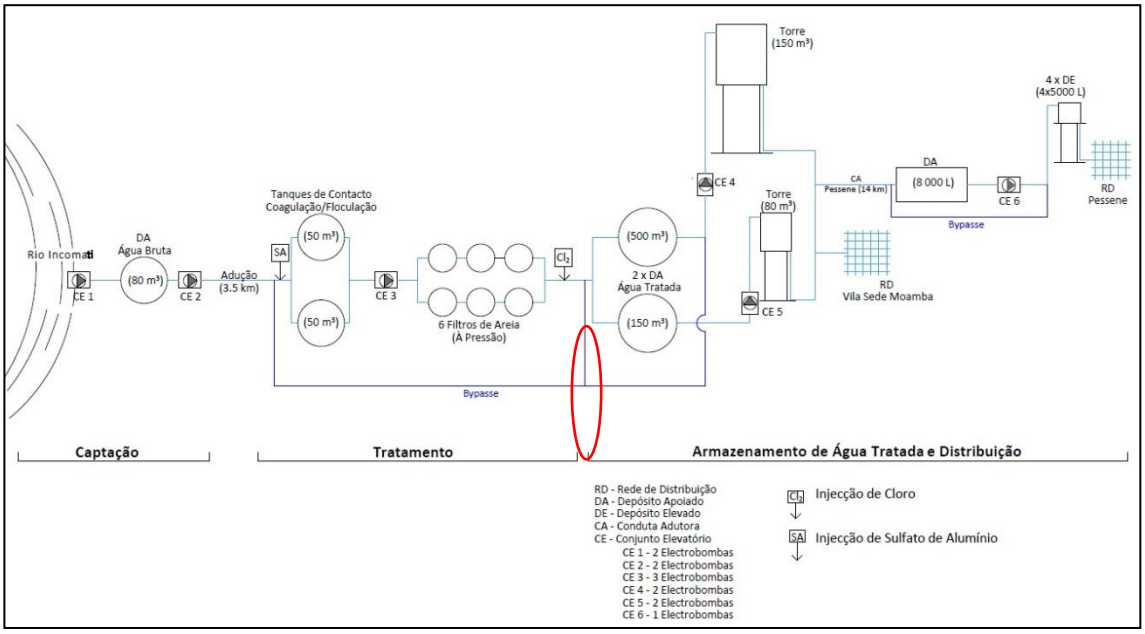

Figure 26: Detail of the bypass in the water treatment station

According to my observations during the fieldwork, it is not only the amount of chlorine which is determined by discretion but the practice of using the bypass itself. Depending on the operator in turn, the practice can become more quotidian instead of exceptional. I saw one of the operators using the bypass more than once when the water level in the 500m^3 ground tank was too low. In this context, instead of being aimed at reducing the time to refill the pies in the distribution network, the practice is aimed at preventing an interruption in the water supply service. This could be one (among others) major explanatory factor to variations in chlorine concentration rates in the water consumed by Moamba's residents.

The water distribution schedule is described below:

- 06:00 - 10:00 hrs: The Moamba's water distribution network valve in the distribution centre is opened.
- 10:00 - 15:00 hrs: some cut-valve in the village of Moamba are closed to give priority to Bairros Central and the town of Pessene.
- 15:00 - 18:00 hrs: these cut-valves are opened again to deliver water to all Moamba's neighbourhoods.
- 18:00 - 22:00 hrs: Moamba's water distribution network valve in Distribution Centre is closed to deliver water to Pessene only.

The water distribution to the neighbourhoods implies the opening and closing of valves located at different points in the network. According to the schedule, between 06:00 and 10:00hrs the valves in the water distribution network are opened to deliver water to all the neighbourhoods of Moamba. In normal conditions, the neighbourhood Bairro Central receive water with two hours of delay and sometimes the pressure in the water flow is low. The operators explain that this is because this neighbourhood is located in a more elevated terrain and the pressure in the system is not enough to make water goes up the slope. The way to deal with this problem of

shortage consists in giving priority to Bairro Central from 10:00 to 15:00 hrs. In order to do so, the valves 0, 2, 3, 4 and 5 are completely closed. Valve 1 and 6 keeps opened (see satellite image # below). In this way the operators of the network close the water flow towards north and west, corresponding to the neighbours of Madinguine, Matadouro, 25 de Junho, and most part of Bairro Cimento (see the Water Network Map 2016). At 15:00 hrs these valves are opened again.

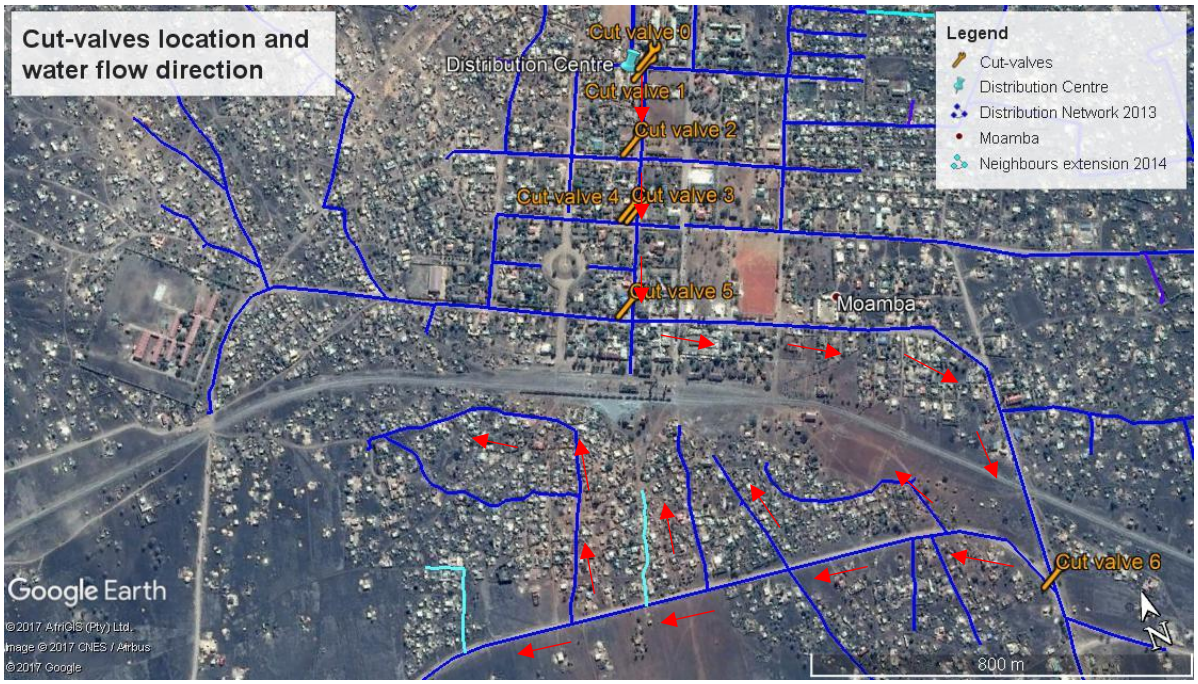

Figure 27: Cut valves location

From 18:00 to 22:00 hrs water is again delivered to Pessene, but this time only for Pessene and not for Moamba. For this purpose, the operators closed the valve towards the Moamba's distribution network located inside the distribution centre.

Similarly to the way the bypass is used, the implementation of the water distribution schedule has also variations. Every time there is a cut in the water supply service for more than one day, the operators can compensate water users by extending the hours of water allocation. For instance, there was a water shortage in Moamba since December 14th until December 17th. Despite the water service was restarted on Sunday 17th, the residents of Bairro Central did not have water until Monday 18th. To give them the opportunity to refill their water storage containers, this day the operator decided to extend the water provision in this neighbourhood until 23:00hrs by keeping closed the valves 0, 2, 3, 4 and 5 during all this time. The next day, to compensate the residents of the rest of neighbourhoods, the operators kept these valves opened until 17:00hrs, instead of closing them at 10:00hrs as the schedule rules. Wednesday 19th the water distribution schedule returned to normal.

The interesting about this practice is that in Moamba the cuts in the water distribution service are quite frequent, reaching a few months to have a cut per week. In this sense, the practice of altering the water distribution schedule after a cut in the service to compensate water users,

which is thought as an exceptional measure, is in the end a recurrent practice. This practice, along with the way the bypass in the water treatment station is used, reveals that water infrastructure is pragmatic not only in the way it unfold in space and time but also in the way it functions. This, in turn, is related to the fact water infrastructure is unpredictable and the actors that interact with it (in this case the operators) have to "break the rules" or make "exceptions" in order to deal with this unpredictable nature. In the next section, I will delve more into the unforeseen ways in which water infrastructure behave by looking at the breakdowns and malfunction that characterize the water supply system in Moamba.

4.8. Infrastructure breakdowns and malfunction

Collins' general manager identify two kind of problems in Moamba's water infrastructure: "power supply quality problems"; and some "challenges" and "limitations" that were not foreseen in the design. About the former, the power system used in the water supply system of Moamba is a three-phase one. When the energy supplied by the provider is not enough, the power system of the water infrastructure stop working. The pumps immediately stop working too. In consequence, the water supply is interrupted in the town. In average, this happens 4 to 5 times per month.

In relation to the design of the water supply system, Collins' general manager talks about three problems. One is a "water hammer" effect produced near to the intake station in the pipe that transport water from there to the distribution centre. The water hammer effect in this point is produced by the slope in the terrain in this area (see the elevation profile in figure 28). When the pumps in the intake station stop working, the water in the pipe suddenly goes back and down. In words of Collin: *"This mobilize big amounts of positive and negative pressure and the pipe used to break in the more fragile point of this section. To avoid this problem is necessary to install hydro-pneumatic tanks in the pipes. These tanks work as buffers to water hammers. But to do this we need to register the frequency of the problem, identify the level of the water hammer and the pressures mobilized and decide where is better to install the tanks"* (Collins' general manager interviewed on 17.11.2017).

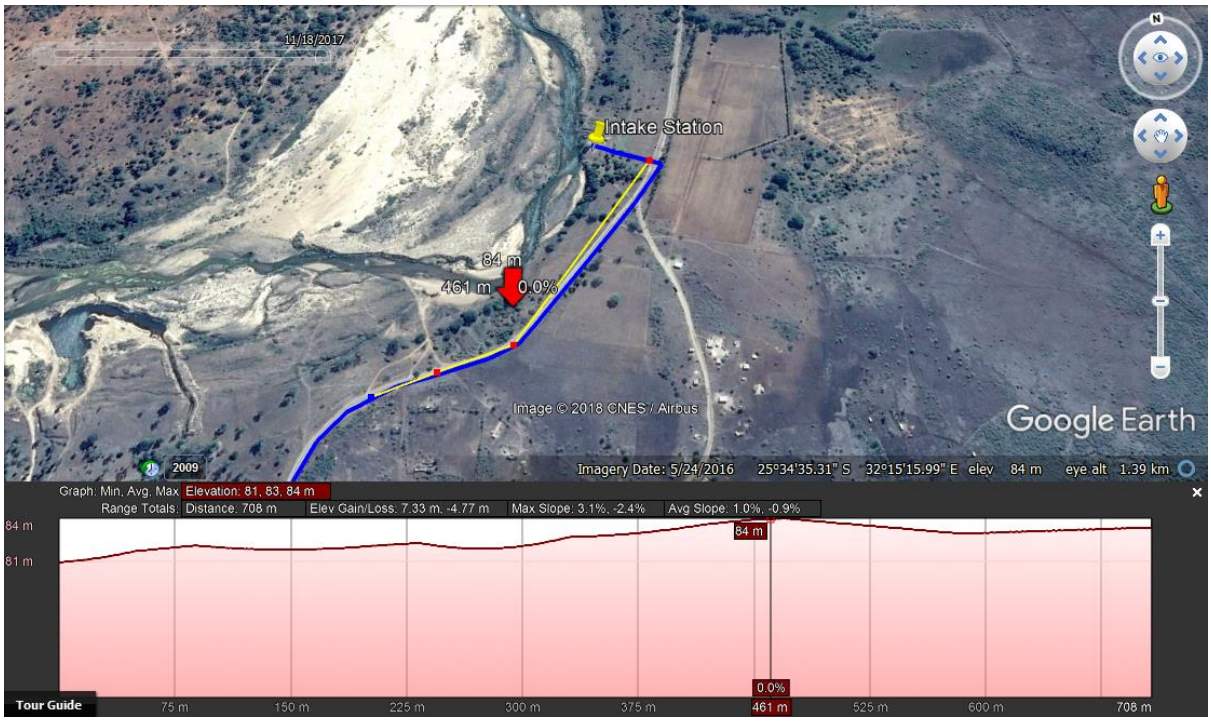

Figure 28: Elevation profile in the area of the intake station

According to IN32, persons in charge of Collins' office in Moamba, the fragility in the pipes is produce by exposing the pipes to the environment (sun and rain) when storing the pipes in the distribution centre (see picture below). Collins do not have an appropriate shed to put the pies.

Figure 29: The picture in the left: broken pipe near to intake station. The picture on the right: stored pipes in the distribution centre.

During my time in Moamba the pipe broke twice in this area because of water hammer effect. Once on Monday 13 of November 2017 and another time on Thursday 09 of January of 2018. On January 10 Herculano, one of the intake station operators, noticed that the sound of the surface bomb had changed. He explained to me that this is usually a sign of a failure. When he went to verify he confirmed that there was a breakpoint in the pipe. This break should have occurred the previous day, explain another operator that participate in the works that were carried out to replace 3 meters of the broken pipe. The crack was not very big, however, this was a six-hour job: 10:00 a.m. to 4:00 p.m. The big effort that would require changing the entire pipe (it would take two days) dissuaded the operators to do it. Instead, they choose to cut the pipe and only replace the affected section. This break was in the same area where the pipe was broken for the first time and was, according to the interviewed operator, for the same reason: the water hammer effect. During the fixing work, two more leaks were detected in the area but they are not serious and were left to being repaired later. The operator responsible for organizing a plan to repair those leaks has not yet decided when to repair them.

A second problem is related with the design of the catchment well in the intake station. The engineers did not take into account the magnitude of the drops in the water table of Incomati river. These drops in the water table occur during the dry season and periods of draughts, and when it happen the pumps are not able to inject water into the system. In consequence, the water supply service is interrupted. Collins' general manager explained to me that the factors behind the drops in the water table goes beyond the design of infrastructure, and are in a great extent beyond the control of the water utility company. Incomati River come from South Africa, where the amount of water diverted is increasing every year. The Mozambican government hope to solve this problem with the construction of "Moamba Maior" dam. However, there is a second factor for the drops in the water table that the authorities are not addressing. This is the erosion of the riverside caused by people that extract sand from the river to use it such a construction material (see picture below).

Figure 30: Extraction of sand from the river bank

Currently, the only measure undertook by the water utility company to deal with drops in the water table consist in rent heavy machines (mechanical excavators) to build a sort of small weir that helps to increase the water level in this point of the river (see image below). Because the water utility company depend on the availability of this kind of machinery to rent, and the fluctuation in the river flow, solve the problem and restart the water supply system take an indefinite time. During my fieldwork, this problem happened on January because of a lack of

rain. In this occasion the interruption in the water supply services lasted almost a week. In the absence of an available excavator, a group of 6 employees worked half a day in trying to manually rebuild a barrier in the river that will help to recover the level of water necessary for the pumps to inject water into the system. Right after these works, Moamba had two consecutive days of rain (most probably was raining in South Africa too), and the system could be reinitiated.

Figure 31: Detail of small weir next to catchment well

Finally, Collins' general manager mentioned that in addition to the error in the design of the bypass, the treatment station does not have a "clarificator". This is an expensive tank that helps to reduce the turbidity in the water. It was not included in the design because the turbidity levels that currently exist, particularly during the rainy season, are higher than those reported by the National Water Direction when requested the design for an extension and rehabilitation of Moamba's water supply system. Given the budget available at that time to build the infrastructure, the engineers in charge of design gave priority to other components of the treatment station and considered that the clarificator was not indispensable.

In addition to the design problems, I could observe the occurrence of breakdowns in different components of the system. Some of them were unintentionally produced by the infrastructure users when installing private connections; by the effect of other human activities, such as the transit of heavy vehicles and the installation process of another type of infrastructure; and breakdowns produced by the interaction of different parts of the water supply system without human intervention. On Thursday 30.11.17 I could see the first and last kind of breakdowns mentioned above. That day two Collins' workers went to check and try to fix a pipe in Bairro Matadouro broken by one user. On our way towards the broken pipe, the workers identify other problems. One was a failure next to a house and an old standpipe. According to the workers, one of the private pipes disconnects from the plastic valve through which it is connected to the distribution network. The private pipe was disconnected by the effect of the water pressure without damaging any piece of this infrastructure. The workers needed to dig approximately 40 centimeters and remove a considerable amount of water to reach the valve. Then the workers closed the valve and leave the hole open to finish the work later.

Figure 32: Breakdown in Matadouro neighbourhood

Figure 33: Picture A: Collins' worker digging to find the source of the leak. Picture B: the same worker is pointing out a private pipe disconnected from a valve.

When we arrived the location of the broken pipe in Matadouro neighbourhood, it turns out that the responsible person of this damage in the network was the chief of one of the blocks of houses near to the secondary school ("Chefe do Quarterón" in Portuguse). He paid to have the right to install an in-house connection, but in order to reduce his costs he decided to buy the materials in the street and make the installation by himself. Because he did not know where other pipes were located in the area, he accidentally drilled six private pipes, producing a big water loss. It was needed to close the water flow in that area, and several residents were negatively affected. Now the responsible for the damages should pay for the materials needed to repair these pipes and the cost of the labour too.

Figure 34: Perforated pipe wrapped in plastic to contain the water leak.

Figure 35: The arrow in sky-blue shows the location of general pipe in the street. The two darker arrows show the location of the private pipes connected to the general one.

The rupture of pipes caused by the passage of heavy vehicles, as the truck in the image below, is a frequent problem in Moamba. The sand in Incomati River is highly valued as construction material and because of this, the trucks that transporting this sand from the river banks to its final destination travels continuously through the main roads of the town. Most sections of water distribution network do not have any type of protection that allows them to support the traffic that currently exists of these trucks.

Figure 36: Heavy trucks transporting sand from Incomati River through Moamba's roads

The same day of Thursday 30.11.17, while I was walking with Collins' workers around Matadouro neighbourhood, we found a leak produced by operators of the electricity supply company. Unintentionally they perforate a private pipe during the installation of electricity pole. At seeing water was being wasted, the owner of a little farm next to the leak decide to use the water to irrigate their land as long as the water be available. Collins operators proceed to close the pipe using a piece of old wire and bury it, hiding the pipe from the eyesight of the residents to prevent further water misuse (see the sequence pictures below).

Figure 37: Picture A: at the background of the image, members of electricity company responsible for the break in the pipe and members of water utility company in the close-up of the image. Picture B: Small water canalization to irrigate small farm. Picture C: Collins' operator is closing the broken pipe with an old wire. Picture D: the pipe was buried.

In words of Jensen (2016), these two types of breakdowns can be interpreted as disruption between activity trails. In this case the activity trail emerged from the electricity supply service and the activity trail of the potable water supply service. Given the absence of an up-dated water network map, the damages in the pipes caused during the installation of electricity infrastructure are common. Other disruption in the water supply activity trail is make by the trucks that transport sand from the river through Moamba, to sell it as construction material.

On 07.12.2017 one of the operators of the intake station notice at 06:00 hrs. a problem in the electrical system of ignition of the pumps. The technitian arrived at 10:00 hrs and confirm there was a problem in the electric system of the superfitial pumps, in a piece called “driver”. When the technitian took a closer look he discovered that the blood of a mouse trapped in this piece had produced a short-circuit. The real problem was that this driver was given as temporal replacement of the original piece by the company that provides Collins with the technical maintenance service. The original driver was in maintenance and there was no other driver available at that moment. It took three more day to solve the problem, period in which the water supply service was interrupted. The electric system in the intake station failed again on 14.12.2017. The problem was solve on 17.12.2017.

Figure 38: Electric system in the intake satation

CHAPTER 5

The water distribution network at the neighbourhood level: the case of Bairro Central

5.1. Design versus built infrastructure

There are three documents with the design of the Moamba's water distribution network: one dated on May 2008 and made by "Tecnica Engenheiros Consultores, LDA" for "Direcção Nacional de Águas, Departamento de Água Rural" (the original design map). The second is from 2011 and is the design map used for the construction of the water distribution network. The construction process was carried out between 2011 and 2013 for a company called Conduril. There is also a simpler version of this map in which the diameters of the pipes are indicated with colours. It also delineates the "bairros" (neighbourhoods) in where the pipes are located and it is dated November 2016. Finally, based on the testimony of one of the operators of the system, I draw in Google Earth the water distribution network that currently exists.
Comparing the design map from 2008 (original design) with the design map from 2011 and the actual characteristics of the build water infrastructure, I identified differences in the length and trace of the pipes, its diameter, and material and the number and location of the standpipes. Bellow, I present the section of the design maps from 2008 and 2011 corresponding to neighbourhood Bairro Central.

In the 2008 design map, the circle in red number one is pointing out a pipe connected to the colonial water tanks (also in red in the image), which in turns are connected to the rest of the water network in the north, crossing the railway underground. In the design map from 2011, this pipe going under the railway was removed, change that was respected during the construction process. The red circle number 2 is highlighting that the pipe located in "Estrada Velha" (Old Road) is not connected with the pipe in the main road that transport water to the south. In the 2011 design map these two pipes are connected, and in fact, it is the only point in which the water network in Bairro Central connects with the rest of the water network. In that sense, these two modifications constitute a major change in the design of the Bairro Central's water network, because it is related with the problem of delay of the water flow after a prolonged cut in the service, problem that characterizes the neighbourhood. The 2011 design map also shows an increased number of pipes, pointed in the image with black arrows.

The number of standpipes presented in 2008 also changed. There are four of them in this map, one in black is the standpipe projected and the other three in red are labeled as existent by that time (the other one in the right side of the image is not part of Bairro Central). The standpipe located in the pipe connected to the colonial water tanks labeled as "existent one" is a mistake:

there is no standpipe in that place. This mistake was corrected in the 2011 design map, which additionally shows a total of seven standpipes, four of them as existent, and three of these existent standpipes in a different location. All these inaccuracies suggest that the design map from 2008 was made without fieldwork.

Another change was made in the diameter of the pipes. The longest pipe in Bairro Central follows the trace of the road known as Estrada Velha. In the 2008 design map, this pipe has three sections. The section in the middle has a diameter of 90mm, and the sections on the sides 75mm. In this map, there are four pipes connected to the main pipe in Estrada Velha: two in the south of the Estrada, and other two in the north. From the left to the right, these pipes have diameters of 90mm, 110mm, 50mm and 75mm respectively. In the 2011 design map, the pipe in Estrada Velha has only two sections: one with a diameter of 75mm and the other with 110mm. There are nine secondary pipes connected to this pipe: five in the south and four in the north. Among the pipes in the south, the first three connects to standpipes. From left to right, the first keep the same diameter from 2008 design map: 50mm. The other four were added to the original design. The second one has 50mm; the third one has 75mm; the fourth and fifth have 50mm. The second pipe of the south in the 2008 map connected to a standpipe was deleted in the 2011 map. Among the pipes of the north, the first one changed the diameter from 110mm in the 2008 map to 90mm in 2011 map. Also, this pipe was extended with two sections, one of 75mm and other of 50mm, which gave it the form of an inverted ‘P’. The second pipe was added and has a diameter of 50mm; the third one change from 50mm in the 2008 map to 75mm in 2011 map. The fourth pipe also added, has a diameter of 75mm.

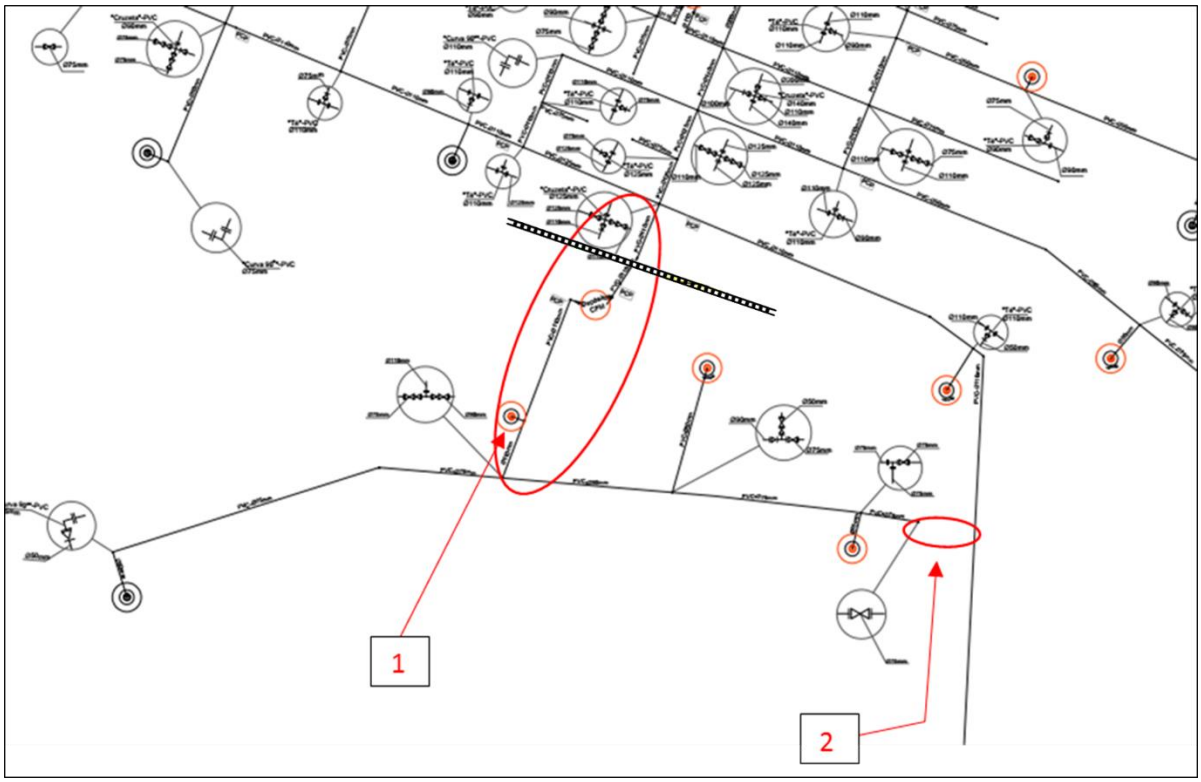

Figure 39: Design map 2008: section Bairro Central

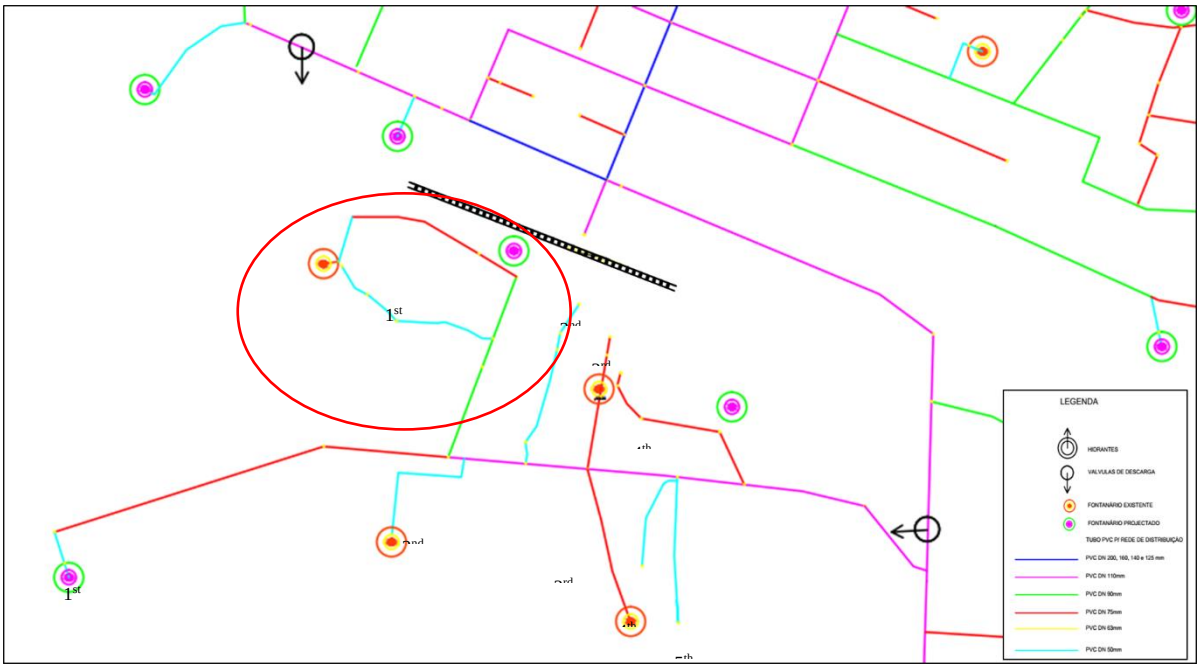

Figure 40: Design map 2011, section Bairro Central

The part of the network with the shape of an inverted 'P' (see circled in red) is a good example of the change in the trace of the pipes. If we compare the shape of the pipes in the 2011 design map with the shape that the pipe have in reality (see satellite image below), we can notice that in the map the pipes follow straight lines, while the satellite image shows that the inverted 'P' deforms in a more narrowed shape just in the area where it connects with a standpipe. The standpipe is also located in a location different to what the design map indicates. This could be explained saying that the maps simplify reality. However, according with two people that worked for Conduril in the rehabilitation and extension of the Moamba's water distribution system between 2011 and 2013[26], the modification in the trace of the pipes happened when they found a building that impedes the passage of the pipe in the area where the map indicates it should, or when they found that the street was too narrow to allow the passage of the machinery needed to install the pipes. Because Conduril project did not include a budget for compensations, most of the time the builders needed to alter the trace of the network in order to not affect the residents.

It was interesting to discover that the design also was modified to fit with the characteristics of the small pieces of infrastructure available for the builders during the construction process. According to the Conduril workers interviewed *"Small alterations has happened for example here* [Distribution Centre], *in the connection of the elevated tank, due to the accessories that we had. The problem was that there was a place where we should use a curve of 45 degrees and we only had a curve of 90 degrees. Here what was used was galvanized iron that is not easy to bend. So we preferred to cut the accessory and make a manoeuvre, but even so, the entrance of the tank was not exactly where they* [the engineers] *projected. This* [change in the design] *was coordinated with the "prosecutor" of the works. So it happened several times that the map said that the pipe had to go through a point but we did not have the accessories and we had to make a manoeuvre to be able to pass"* (Claudio and Gildo interviewed on Friday, 05.01.2018). The way in which the materiality and shape of these small pieces of infrastructure oppose resistance to the will of engineers and builders, resembles Pickering's concept of "material agency" and its emergent nature.

[26] Both workers were interviewed simultaneously on 05.01.2018.

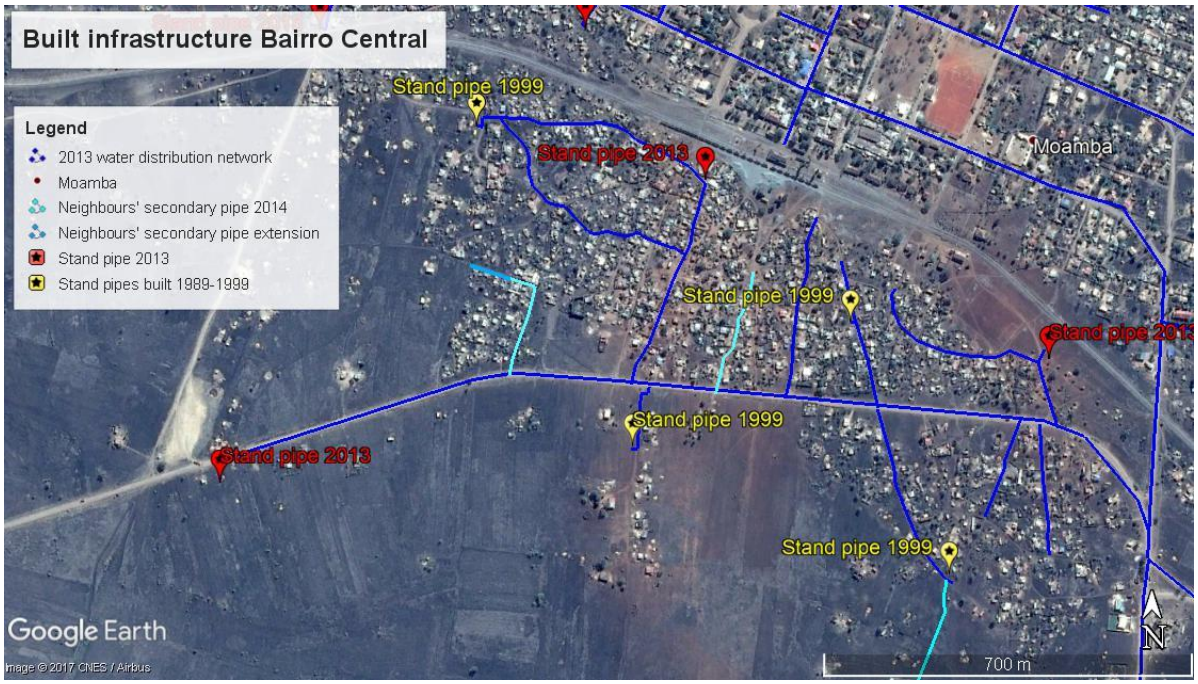

Figure 41: Build infrastructure 2017

The satellite image above also shows in sky-blue the existence of sections of pipe that were installed by the neighbours. These are second-hand pipes, unearthed from their original location in different parts of Bairro Central in order to connect them to the general pipe in Estrada Velha and bring water to their respective neighbourhoods. This modification of the water network will be subject to a further analysis in the following section, where I will talk about Quarteirão 11.
The increment in the number of secondary pipes connected to the main pipe in Estrada Velha is translated in a significant increment in the length of the network. To calculate the approximate distance covered by the pipes using Google Earth I overlapped the design maps from 2008 and 2011 to the satellite image of Bairrlo Central and then I used the Ruler Tool of this software to measure the length of the pipes. This exercise revealed that the design maps do not reflect the real shape of the pipes (see figure 42). This is because the design maps do not follow the trace of the streets, which is in practice what defines the shape of the pipes. In the case of 2008 design map, the measurement of the projected pipes yielded a length of 2.45km. If we accommodate the trace of the pipes to the real form of the streets through which the pipes would pass through, the length is 2.61km. The built water network in Bairro Central on the other hand sum 5.4km without counting the extensions made by the neighbours, which in total sum 6.18km.

Figure 42: Overlapping 2008 design map and satellite image of Bairro Central

Another major change in the water distribution network is related with the closure of the standpipes projected in the 2011 design map. The original project commissioned by the National Water Direction to rehabilitate and extend Moamba's distribution network contemplates the increment in the number of public standpipes from 10 to 29, and this design was respected in the construction. However, less than two years later of inaugurating the new network the water utility company decided to close down all the standpipes. I could identify three different narratives to justify this decision[27]. One is that standpipes become an unintended source of power for particular actors, the standpipes money collectors, making the utility company unable to exert a total control over the profits produced from the water sells in these points. Collins' general manager said that the difficulty in controlling the income produced in each standpipe was that the money collectors did not even need to manipulate or modify the standpipes' water meters in order to steal money because the readings of these gauges were not accurate[28]. In this way, standpipes acted as wellsprings of power, similar to what Meehan (2014) refers to as "tool-power".

According to a second narrative, also given by Collins' general manager, the standpipes were closed because of the increment of in-home private connections which left public standpipes without clients. However, other empirical data show that standpipes' customers had not completely disappeared. For instance, even current Chefe do Quartirão 11 is interested in install a well and standpipe in his neighbourhood to use it as a buffer against prolonged interruptions in the water distribution service. Of course, he can be also interested in using the standpipe as a personal source of income, but it shows that there are still potential users for this type of infrastructure. There are also several people that cannot afford the materials to install a water-

[27] See chapter five.
[28] Interview with Pedro Cardoso on 31.01.2018.

tap at home. As consequence, they need to buy water from their neighbours, which according to the testimony of some residents of Quartirão 11, is an uncomfortable situation since it can be felt as a relationship of subordination that affects other dimensions of social interactions as well[29].

The third narrative that could explain the closure of the standpipes is associated with the wider political process occurred in Mozambique in recent years. When the Water and Sanitation Infrastructure Administration (AIAs in Portuguese) gave the administration of the Moamba's water infrastructure in a five-year concession to Collins, it did it as part of a new strategy called "delegated management". This strategy looks to promote the autonomy, efficiency and financial viability of the secondary public water distribution systems by delegating its administration to private operators.[30] And this strategy is part of a more general policy that promotes the development of the private sector in the country. Public standpipes are very compatible with the political tradition of communism in Mozambique, but it is contradicting with the neoliberal policies promoted by the government and incompatible with the goal of the private utility company of increasing its profits.

5.2. Functioning and modification of the water infrastructure

At the beginning of 2013, when the water supply system started to operate, the water distribution schedule rule that Moamba village receives water from 06:00 - 09:00. From 09:00 - 16:00 the Moamba's water network get closed and all the water flows towards Pessene. At 16:00 hrs Moamba's distribution network valve was opened again, until 18:00 hrs when the pumps were stopped and water provision was cut until next day. But, according to IN33, one of the operators of the system, the pressure and the hours per day that residents of Bairro Central receive water started to decrease progressively, until 2015 when the situation was so bad that was urgent to implement a solution. According to him the cause of the problem was the increment of the system's users. Collins' general manager, IN32 (the head of Collins' office in Moamba), and IN36 (responsible for monitoring the water quality in the system and also operator of the system) coincided with IN33 in the explanation: This neighbourhood is located in an elevated terrain and there is not enough pressure to make the water flow up the slope. Collins' general manager clarified that every time the system is stopped, the water in the pipes in Bairro Central is completely withdrawn. This reduces the water pressure and it takes longer to refill the pipes again. This is why when the system is re-started the residents of Bairro Central complains that all the rest of neighbourhoods have water but them.

Bairro Central is separated from the neighbourhoods in the north by the railway. The shorter way to connect the distribution network of Bairro Central with the rest of the network in the north is by installing an underground pipe that crosses the railway at a point next to the train station, just how it used to be during colonial times. This pipe does not need to be longer than 150m. However, because of a lack of understanding between Conduril and the CFM (Mozambican Railway Company), it was decided that the pipe that currently conveys water to

[29] Interview with IN29 and IN21 on 09.01.18.
[30] See official webmail of AIAs, http://www.aias.gov.mz/index.php/quem-somos.

Bairro Central should not cross the railway in this point. Instead, it should cross the railway at its intersection with the highway, traveling a distance of approximately 2,600m. The green arrows in the satellite image below show the water flow towards Bairro Central.

Figure 43: Water flow and elevation profile in Bairro Central

This decision not only determined that water take a long round before reaching Bairro Central. Water also needs to go up a small slop on its way to this neighbourhood, because the terrain in the north is 3m more elevated (see the elevation profile in figure 43). These two combined factors, the extension of the pipe and the slope in the terrain, increase the time needed to supply water to this neighbourhood. When there is no problem with the water pressure in the system, water takes two hours to get from the Distribution Centre to Bairro Central. However, during the dry season or during droughts in the rainy season, the water table in the river goes down, reducing the amount of water that the pumps in the intake station can inject into the system, which leads to a decreasing in the water pressure. This worsens the situation and reduces the hours per day of water supplied to Bairro Central. In contexts of protracted interruptions in the supply service, the slope prolongs the situation of water scarcity. By gravity, the water in these pipes tends to retry and flow back to the south (see arrows in orange in figure 44). Eventually, the pipes get totally empty and when the system is restarted and water flow again, the residents have to wait on average one more day to have water flowing in their water taps. The fact that they can see how all the rest neighbourhoods have water except them increase their dissatisfaction with the utility company and make them aware of the social inequity situation in which they live.

Figure 44: Water backflow in Bairro Central

Taking this into consideration, the provisional solution currently in use consist in two measures: first the water distribution schedule was modified to extend the hours per day of the water supply service for both Moamba and Pessene, and dedicate three hours per day (from 10:00 to 15:00 hrs) to give priority to Bairro Central. In order to do so, the second measure consists in closed the valves 0, 2, 3, 4 and 5, procedure described lines above. However, the solution is temporal because the users of the system keep growing in number and the problem is not completely solved. According to with IN42[31] (resident in the neighbourhood since 1999) during the rainy season people have water from 07:00 or 08:00 hrs to 17:00 hrs without interruptions in the service. But during the dry season, people have water only from 11:00 or 12:00 hrs to 17:00 hrs. IN33 summarizes the situation in the following terms: *"The problem is to make the water reach the neighbourhood. Once there, it will be water all day"*[32]. And continue explaining that during the dry season, when the water level in Incomati River goes down there is less water in the system and the pressure goes down too.

The final solution would be to connect the neigbourhoods Central and Matadour by installing a pipe under the railway (see the section marked with a red line in figure 45), which would close the system in this part and invert the direction of the water flows. By gravity, the water would flow from north to south. This solution is not implemented because of its cost: the works need to be done by the railway company staff and this company demand Collins the payment of a kind of "internal taxes". The amount was estimated at 24,000 MT (342.85 EUR in the current exchange of 70MT per EUR), an investment that, according to Collins' general manager, is not a priority for the utility company right now. Their attention is focused on increment the number

[31] Same interview.

[32] This comment was made during the interview with IN42 (resident in Bairro Central) on Wednesday, 29.11.17

of connections. A bit more permanent solution than the current in use, but still temporary, consist in install a “non-return valve” in the intersection between the main pipe and the pipe that transport the water to Bairro Central. This would prevent that the pipes in this neighbourhood get empty every time the system is stopped, however, the problem with the pressure persists and still needed to open and close every day the valves 0, 2, 3, 4 and 5.

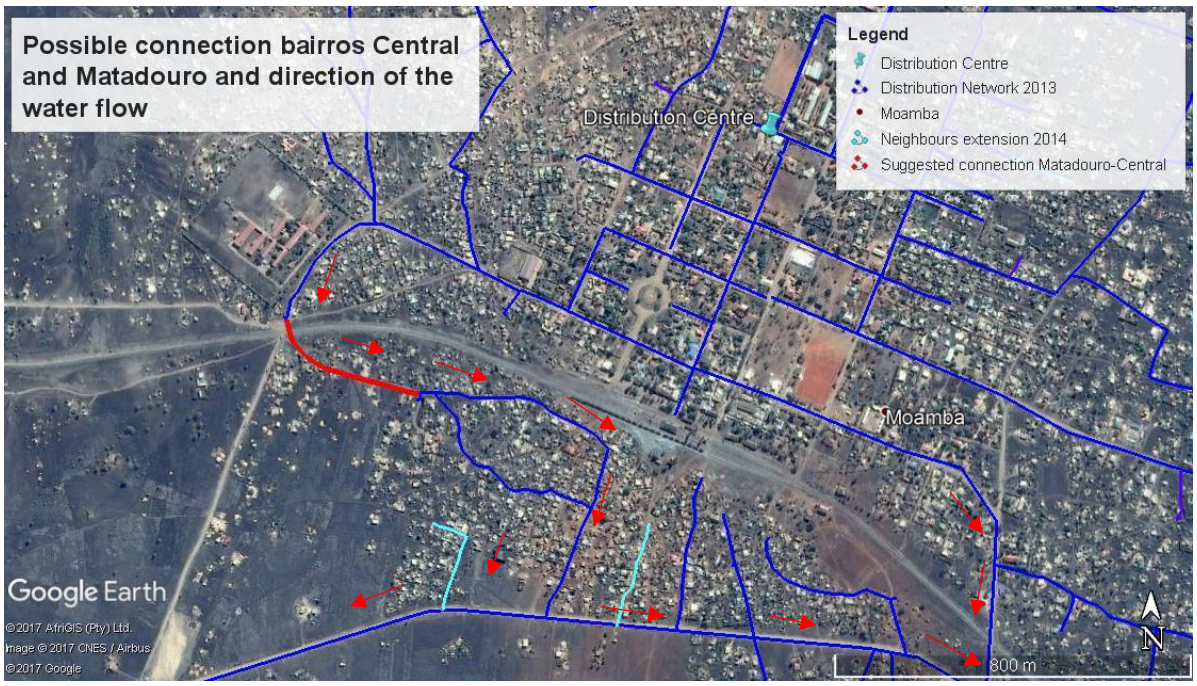

Figure 45: Possible connection between neighbourhoods Central and Matadouro

The non-return valve was bought but could not be installed because the person that bought it brings a valve for a pipe of 90 mm instead of 110 mm that actually the pipe has. According to Collins’general manager, the way they currently manage the problem consists in use a “cut valve” to close the water that flow towards Bairro Sul and give the system some time to fill up the pipe towards Bairro Central. According to him, when designing the network the engineers considered that the area will not grow too much and consciously avoid to cut the railway at this point.

Another problem identified in Bairro Central is that residents were complaining about false readings in the water meters. According to IN33 and Collins’general manager, the false lectures in the meters are generated by air in the pipes that go out through the taps. To solve the problem Collins has installed “air-valves” in the area. Every time the pipe is refilled the valves automatically work extracting the air preventing its passaging through the water meters. However, during my visit to Bairro Central on November 29, IN33 explain that the problem is not completely solved. To do so it is needed to install at least two more air-valves in the main pipe in the road (see figure 46). The location between these two air-valves marks the section of the terrain that is more elevated.

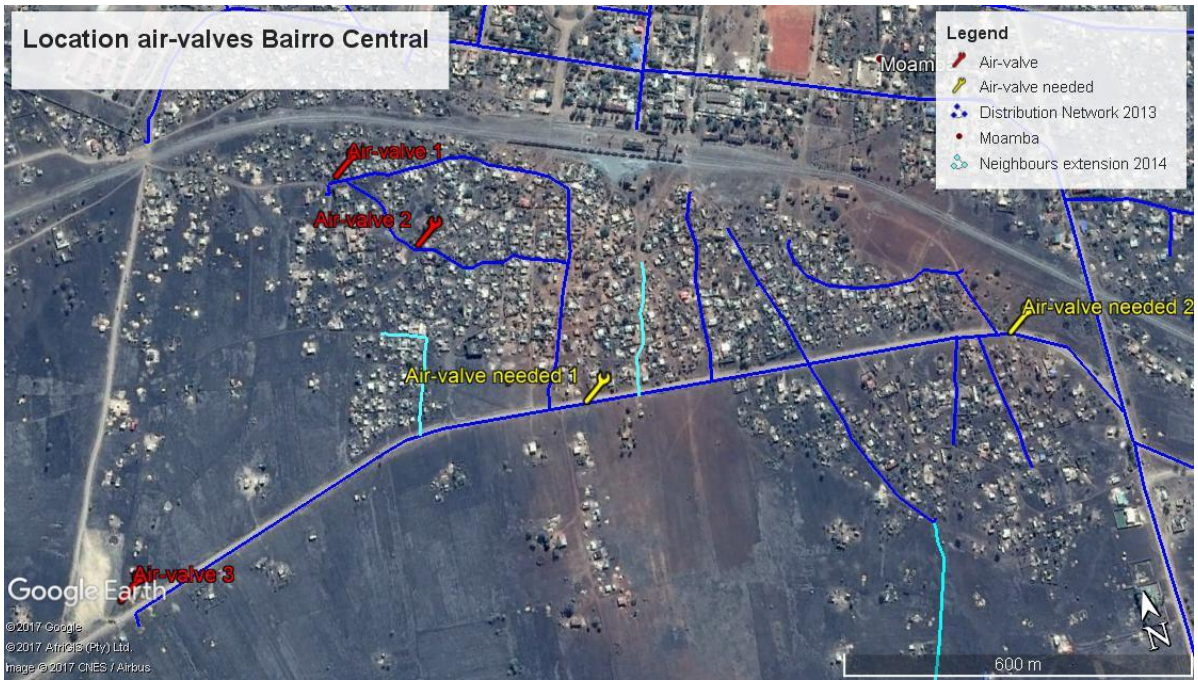

Figure 46: Location of air-valves in Bairro Central

CHAPTER 6

Getting inside the neighbourhood: the case of Quarteirão 11

6.1. Description of the water network components in Q11

The Quarteirão is the smallest unit in the administrative organization of Mozambique. It is composed of an undetermined number of houses and it is under the supervision of one person. The formal title of this person is *Chefe do Quarteirão*, which could be translated as block boss. He or she can be assisted by one or more deputies, who in turn can be in charge of approximately ten houses. The block boss is elected by the residents in the quarteirão, and it is a lifetime position. The block boss duty is to ensure the welfare of the area, which in practice means working as a mediator for the resolution of any kind of conflict between the neighbours, and working at trying to solve any problem affecting the residents of the block.

Quarteirão 11 (hereinafter Q11) is located in the south-west of Bairro Central, next to the road called *Estrada Velha* ("old road"). According to the block boss, Q11 consist of 60 households. The water distribution network in Q11 can be described in terms of three hierarchical levels. The first level corresponds to a PVC pipe that follows the trace of "Estrada Velha" (see in blue and purple in figure 47). It starts on the main road that serves as the entrance to Moamba, the highway 570, to finish in a closed standpipe after 1,894 m. This pipe has two sections: one of 110mm diameter and the other with 75 mm. Here I will refer to it as the primary pipe. The second level usually corresponds also to pipes installed and administrated by Collins, with diameters of 75 mm and 50 mm. However, in the particular case of Q11, this second level correspond to a second-hand copolene pipe of 63mm of diameter, unearthed from its original location by the neighbours in order to recycle it and install it in its current location for their benefit (see in sky-blue in figure 47). I will refer to it as the secondary pipe. Primary and secondary pipes are referred by the neighbours as "general pipe" in opposition to the third level corresponding to the families' private pipes that transport water from the secondary pipe to their water taps. These pipes are made also on Copolene and have a diameter of 25mm. I will refer to it as the tertiary pipe or private pipes.

Table 4: Characteristics of water pipes in Quarteirão 11

Pipe	Material	Diameter	Picture
Primary	Polyvinyl Chloride (PVC)	110mm and 75mm	
Secondary	Copolene	63mm	
Tertiary (private pipes)	Copolene	25mm	

In Q11 there are 25 houses with private connections that receive water from the secondary pipe. Others houses, those located near to the road Estrada Velha, connect their private pipes to the primary pipe of 90 mm (in blue and purple in the image). The houses without private connections need to buy water from their neighbours, from the houses in Bairro Cimento or ask water to the block boss. According to him, he does not charge for water because is his responsibility to take care of his people.

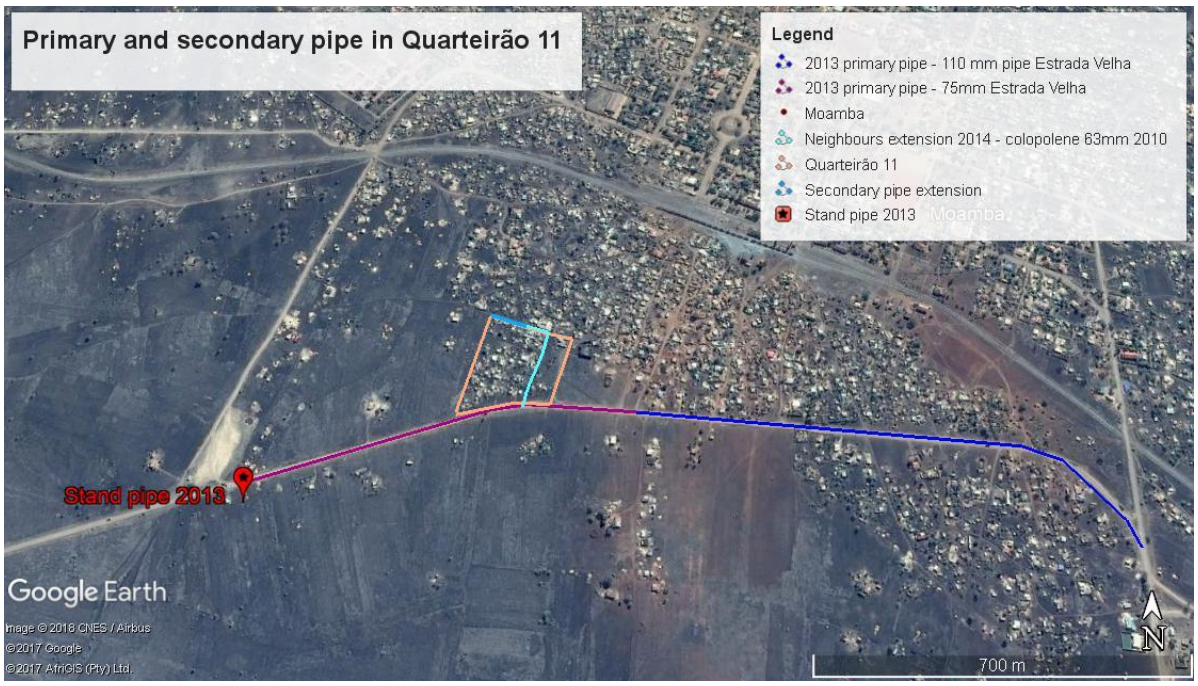

Figure 47: Primary and secondary pipes in Quarteirão 11

6.2. The primary pipe

The primary pipe is in fact composed of several pieces of PVC of 6m length each (see picture below), which cover in total a distance of 1,894 m long. This sectioning facilitates to fixing the

pipe when breakdowns occur because the operators of the system only have to remove and change this 6m of the pipe.

Figure 48: Detail of 6m long PVC pipes in Collins' office

According to Collins general manager, the characteristics of the network to which the engineers pay more attention are the pipes' diameter, its material, and the deepness in which the pipes are buried. The material of the pipes provided and administrated by Collins, polyvinyl chloride (PVC), has been chosen based on the criterion of resistance (the pipes should resist the water pressure) and the future availability of the pipes in the market. A "safe deepness" for the primary pipe is 1m and for secondary network 30 to 50 cm. The primary pipe has two diameters: from the main road of Moamba (Highway 570) to the cut valve 15 (see in blue in figure 48) the pipe has a diameter of 110mm. From here to the end of the pipe, market by the standpipe and the air-valve, it has 75mm diameter (in purple in the same figure).

Other components of the primary pipe are ten buried cut-valves (marked in orange in the image with the numbers from 6 to 16) and one air-valve (in red in the image). Valves 7, 10, 12, 13, 15, and 16 are valves that cut and opens the flows towards the secondary pipes of Bairro Central. The rest of the valves have the same function with the secondary pipes that deliver water to Bairro Sul. One of the operators of the systems explains that because Bairro Central is located in a more elevated terrain, the water tends to flow by gravity towards Bairro Sul. This is why the Bairro Central valves are always open while sometimes Bairro Sul valves have to be semi-closed to increase the water pressure in Bairro Central and help to fill the pipes again after a prolonged cut in the service. These valves give to the utility company the power of cutting the flow towards the neighbourhoods; however, some residents have learned to manipulate this valves. Is the case of Q11, the residents close the valve 16 in order to fix the leaks in their secondary pipe by themselves. I did not have the opportunity to see this and was not possible to identify which neighbours are in charge of operating the valve. The air-valve function is to

release the air contained in the pipes, especially when the pipe is refilled with water after a prolonged cut in the service.

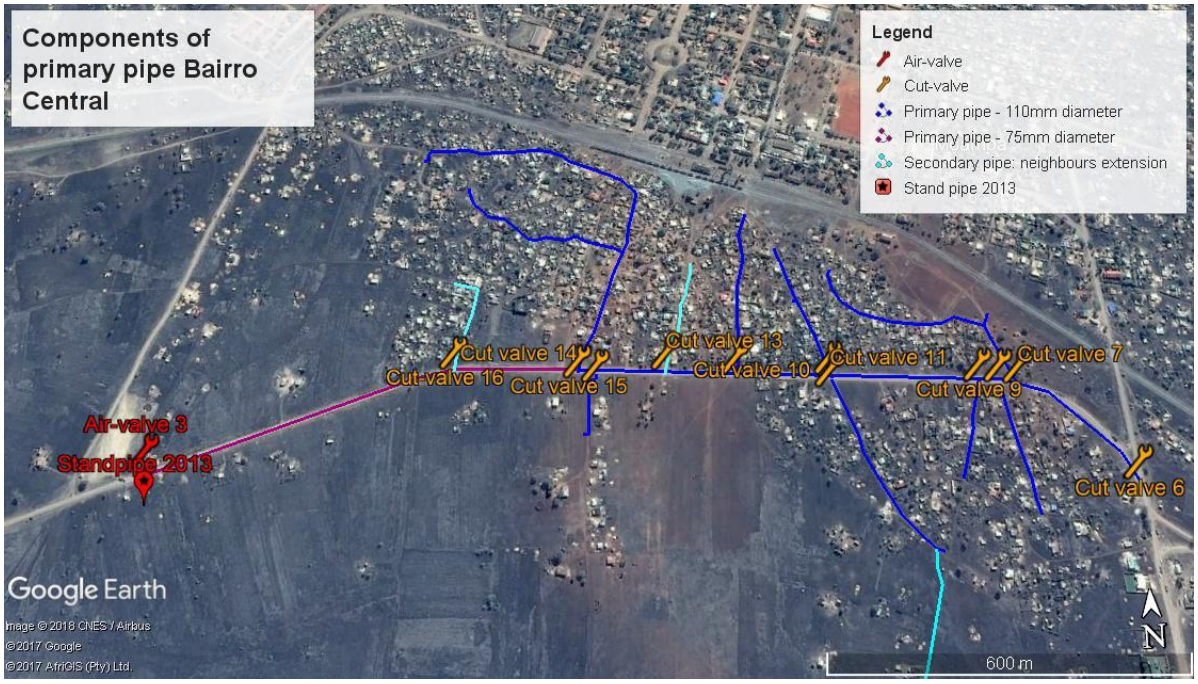

Figure 49: Components of the primary pipe in Bairro Central

The location of this pipe was decided by the consultancy company responsible for the original design, "Tecnica Engenheiros Consultores, LDA", which is captured in the 2008 design map (see documents attached in the end), most probably with the intervention of the client Direcção Nacional de Águas, Departamento de Água Rural". It is worth it highlights that there were other pipes installed in Estrada Velha before (see the section "The evolution of Moamba's water distribution network"). When explaining the location of the pipes, Collins general manager say: *"the numbers were foreseen but not the pattern of settlement*"[33]. For him this is important because characterize the way the water network develops: *"the water network follows the people and not the other way around*". Then, he extend the explanation by saying that the pipes are built under the avenues and streets of the settlements because in this way the installation and maintenance of the pipes are easier. This means that the more organized the structure of the settlement the easier the development of new connections.

From its construction, the pipe has had no changes in its layout, form or materiality. However, two cut-valves were installed in 2014 in hand with the secondary pipes installed by the neighbours: cut-valve 13 and cut-valve 16 (see in figure 49).

6.3. The secondary pipe: a pipe installed by the neighbours

[33] Interview on November 2, 2017.

The secondary pipe in Q 11 was installed in 2014. It is made of copolene. It has a diameter of 63mm, and an approximate length of 246m[34]. Currently, the pipe is composed of eight pieces put together with seven joins (see figure 50). The connection with the primary pipe in Estrada Velha is through Valve 16, which in turns connects to a clamp.

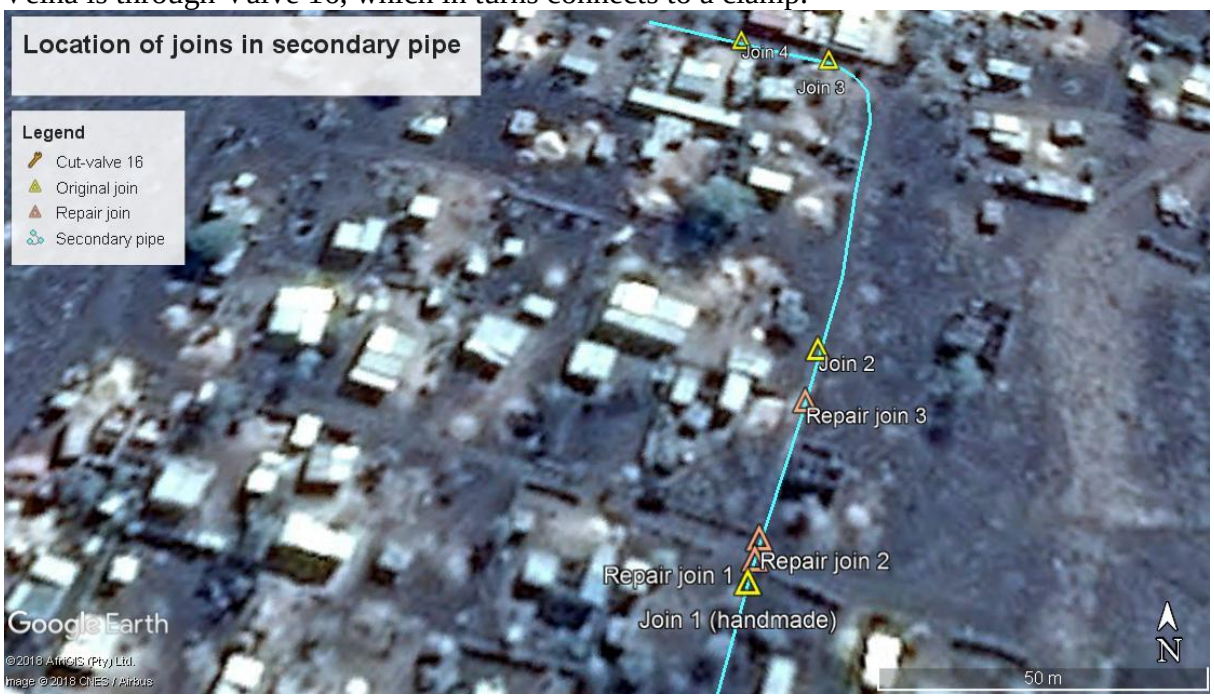

Figure 50: Location of joints in secondary pipe

6.3.1. The installation process

The secondary pipe has the form of an inverted 'L' and crosses Q11 through the only street oriented on the North-South axis. This layout was decided in one meeting held by the neighbours of the Q11; meeting promoted by its block boss. The original idea of the block boss[35] was to use a pipe to cover the whole contour of the Q11, forming a kind of inverted 'U'; but when asking why this did not happen I receive the following explanation: the pipe that the block boss got from the Secretario do Bairro Central was not long enough and later, when they decided to unearth and re-use some old pipes in the area, not all the neighbours had the willingness to participates in the works; so when the pipe reached the location that allows the access to the households who did participate in the installation works, the neighbours stop working.

In other words, the shape and location of the secondary pipe was based on the location of the houses of the families that were willing to work in the process of unearthing the old pipes and digging the new place for its installation. The logic was that the location of the pipe should benefit all those houses that participated in its installation. That is why the pipe turns to the left in its current location, in the street that marks the northern border of Q11 with Quarteirão 3 (see

[34] It was measured with Google Earth

[35] This information was provided by the block boss of Quarteirão 11 during an informal conversation.

figure 51), and not in a previous street: the pipe needed to reach that street to benefit some families of Quarteirão 3 that also contributed to the process. Another way the neighbours explain this is that they were not willing to work for others, benefiting people that did not want to work or contribute money to buy the joints[36]. One alternative to the current trace of the secondary pipe would be to put the section of the pipe that goes from Estrada Velha to the northern border of the Q11 in its right border. However, in the right side of Q11 there are no houses and this means no residents interested in cooperate with the pipe installations works and the cost of the materials needed. One aspect to highlight is that not all the neighbours that participated in the works were present in any kind of conversation about the form and location of the pipe. One of these neighbours told me that she assumes that the layout of the secondary pipe was decided by Q11 block boss, based on his own criteria about the best location for this pipe[37]. In this way, she explain that she did not even know about the meeting but this is probably because she spent most of the day working out side Q11 and she usually does not participate in the neighbourhood meetings.

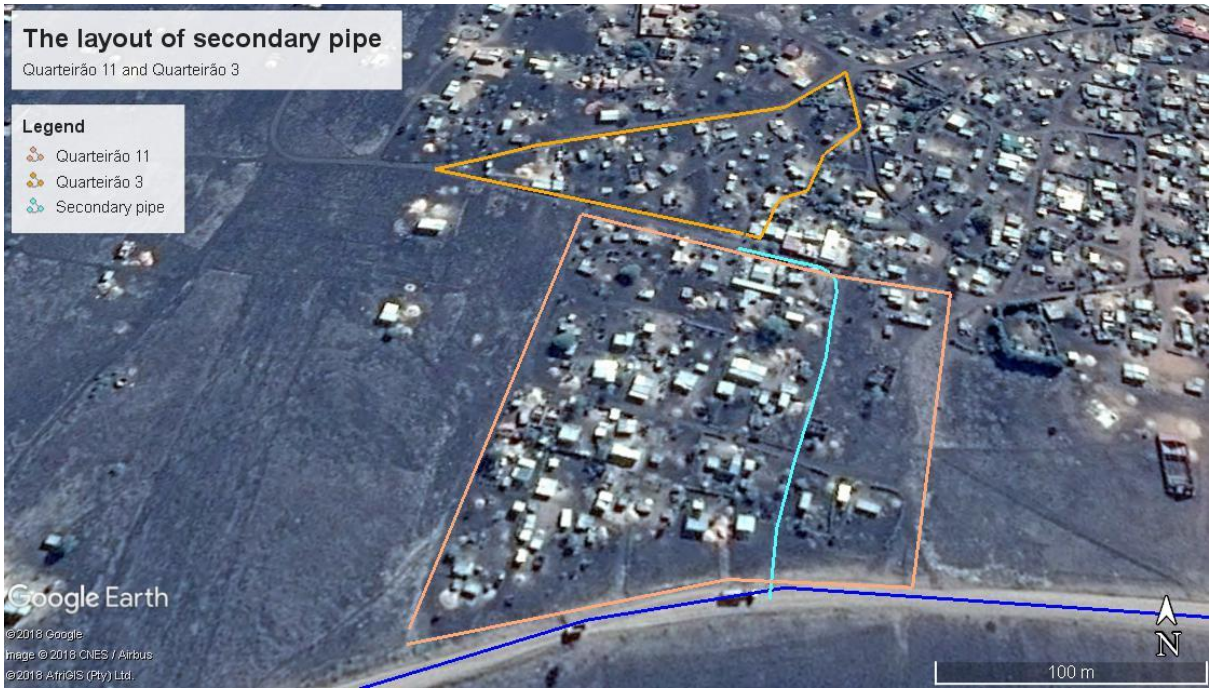

Figure 51: The layout of secondary pipe in Quarteirão 11

According to the block boss of Q11, even before thinking to recycle old pipes to use them as secondary pipe, he asked to Conduril[38] for a pipe to supply water to Q11. The idea was that this pipe would come out as a branch of the inverted P-shaped pipe, to follow a parallel to the primary pipe installed in Estrada Velha (see the pipe in white in figure 52). At the beginning the answer was positive, but the pipe was never installed because some residents living in the

[36] This discourse was repeated during different interviews with residents of Q11 connected to the secondary pipe. The interviewed residents were IN9, IN17, IN22, IN23, IN15 and the block boss of Q11.
[37] Interview with IN11 on 14.01.2018.
[38] Conduril was the company in charge of rehabilitation and extension of Moamba's water supply system.

centre of Bairro Central (see their approximate location circled in red in figure 52) deny permission to remove their bathrooms and kitchens obstructing the trace of the pipe[39]. In September 2013 Collins started to operate the water distribution network. In 2014 after some informal conversation the neighbours of Q11 and some from Q3 agreed in to go to Collins' office to ask a pipe in the area. Around 20 people went the first time with the Chefe do Quateirão 11 and one of his deputy. Because not all had the same schedule, other group insist other days. There were informed that Collins did not have more pipes and they need to buy one for themselves. They receive an estimated cost that none of my interviewees remembers, but all coincide that was an amount of money that they cannot afford.

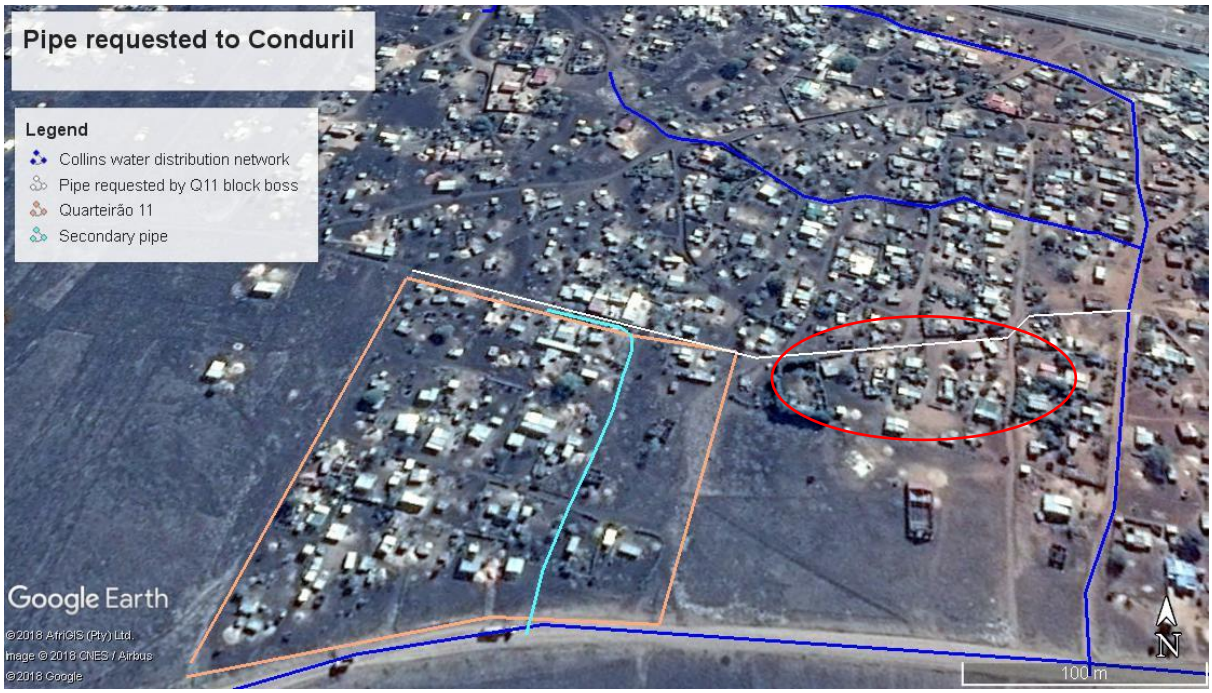

Figure 52: Pipe requested to Conduril during the distribution network construction process

Sometime later, Q11 block boss saw an opportunity when he discovered that there was a pipe not in use stocked in the place of the Secretario do Bairro Central. He asked it to Bairro Central secretary and he agreed but once in his power was evident that the pipe was not long enough. Among the interviewees that provide information about the secondary pipe installation process, two said that in the looking for alternatives one of the neighbours proposed to re-cycle the old pipes buried in the area[40]. A third one claimed that the idea came from Q11 block boss[41]. In any case, all the neighbours had already seen some unearthed pieces of these old pipes, so the idea was approved quickly. Then a group went to the place to see the pipes and there decided that those pipes would work. Those present in these meetings were informing to the rest of the residents about the plan, and the need to go to dig to remove the pipe, transport them to the new place, and dig there again to install the pipe. The pieces of pipe were unearthed and removed

[39] Explanation gave it by the Bairro Central secretary and Q11 block boss. However, they did not specify the location of these neighbours or their number.
[40] Interview with IN15 on 19.12.2017 and with IN22 on 29.12.2017.
[41] Interview with IN9 on 20.12.2017.

from their original locations, one next to Estrada Velha (in pink in figure 53), and the other from an agricultural terrain in the other side of Estrada Velha (in salmon in the same figure).

Figure 53: Original location of recycled pipes in Quarteirão 11

Once the neighbours had the pipes needed in place, Q11 block boss talked with people of Collins to request help in the connection to the primary pipe in Estrada Velha. They did not have problems with that and agreed to send a technician to do the work. According to the interviewees cited before, people in Collins knew what was happening and did not complain. In Collins Q11 block boss received the list of additional materials they need to buy and estimated costs. With this list the block boss request money from the Q11 households: according to him 50MT per household.

The neighbours worked from 4am to noon. One day took to remove the old pipes from their original location and other four days digging in the new place where the pipe was installed. One interviewee said that this work was very heavy and difficult, which was the reason why they did not continue removing more pieces of pipe but only worked until reaching the area of the neighbours that would be benefited by the pipe[42].The interviewees refused to specify the name of the people who did not contribute to the installation of the secondary pipe. However, the general perception is that some families did not participate because they were expecting to be able to benefit from the pipe without working. Others did not participate because given that they did not have money to afford the installation of their own water tap, they thought that working for the secondary pipe did not make sense. In words of one interviewee, some applied the following logic: *"I do not have money to install a water tap in my house. Given this, why should I work installing this pipe? I will not be benefited from it"*[43].

[42] Interview with IN22 on 29.12.2017.
[43] Interview with IN15 on 19.12.2017.

Those that refused to participate were prohibited to install private connections. Nowadays, the requirement to make a connection to those who did not work is to pay 500MT, money that is collected by the block boss of Q11 to be used in cases they need to invest in reparations. Those who do not have water taps is because of lack of money to afford the materials. These people need to buy water from the neighbours and they are allowed to pay at the end of the month. Among 60 households I could identify only 6 without water-tap.

There is another group of neighbours that did not contribute to the installation of the secondary pipe in Q11; they are the households that made privates connections directly to the primary pipe in Estrada Velha. Some of these households are much closer to this pipe, such household 25 (see figure 54). These households took advantage of their privileged location and save money at buying the needed materials. Others households as 19, 20 and 21 however, are not so close to the primary pipe, and this means a greater investment in the 25mm diameetr copolene pipe used in the private connections. However, for them was more important the desire to avoide the problems related to being connected to a second-hand pipe. Among these problems, my interviewees mentioned the need for spending time on meetings to address the issues related to the pipe (from its installation to the frequent breakdowns that characterize its functioning); the emergence of conflicts between neighbours (for instance discussions about who do not want to work or give money); and the need to periodically contribute with money to fix the pipe every time there is a breakdown. For them even when they invested a greater amount of money in the beginning, at the end, they are saving money with their private pipe connected directly to the primary pipe because they do not spend money in reparations. Most probable, the block boss of Q11 had the same reasons when decided to move his private connection from the secondary pipe to the primary pipe.

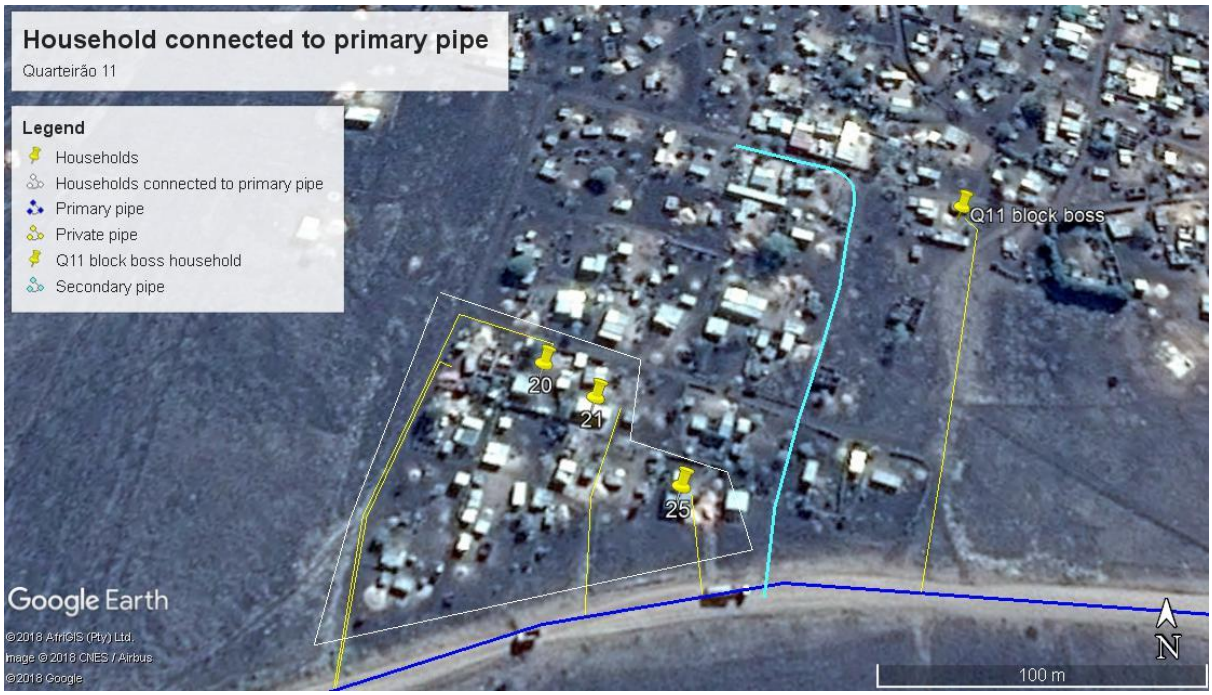

Figure 54: Households connected to primary pipe

6.3.2. Changes in the pipe

One type of changes registered in the secondary pipe corresponds to the change in the number and nature of the joints that hold together the different pieces of tube that make up the secondary pipe. There were four original joints when the secondary pipe was installed (see in yellow in figure 55). The first joint to be changed was Joint 1. Two residents of Q11 that participated the installation of the secondary pipe, IN15 and IN14, explained that Joint 1 "bust" in several occasions (IN15 mention this happen at least 4 times) and after this happened, the neighbours did not want to spend more money to replace this piece. The solution in this case was to replace the original joint by one made by hand. IN23 helped by other neighbours, inserted the end of one of the pieces of pipe into the other. To do this, one pipe was heated with fire in order to make it soft and then widen in the part in which the other pipe would be inserted. Once this was done, they proceeded to tie-up the section in which the ends of the two pipes were joined with a piece of rubber, recycled from an old tire. Then, they used a piece of an old wire to secure the joint.

According to the testimony of the neighbours interviewed, this artisanal joint has not generated major problems. Indeed, there are no signs of new leakages, however, regardless of the effectiveness of this work, it is interesting to note how water users, driven by the need to fix a fault in the pipe with the few resources they have, become de facto in a kind of engineers.

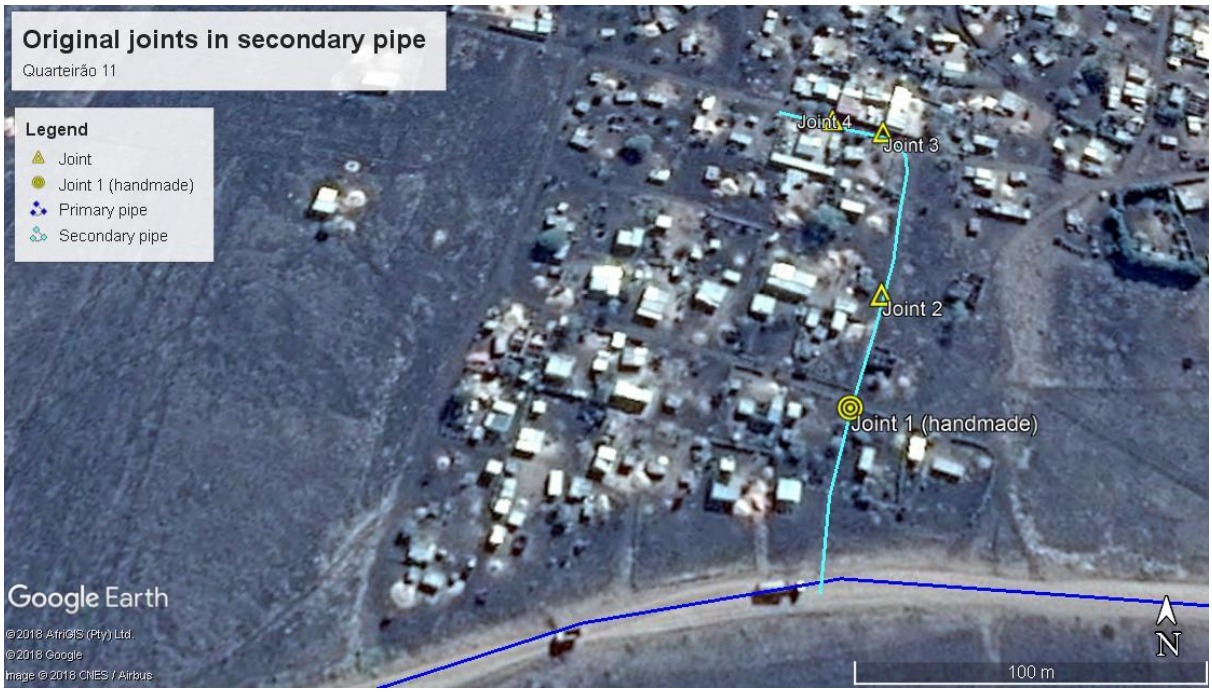

Figure 55: Original joints in secondary pipe

Other three joints were installed to repair leaking problems (on pink in figure 56). "Repair joint 1" and "Repair joint 2" were installed to replace one section of the pipe that present breakdowns from time to time. This intersection is highly affected by passing cars, which is a factor to explain the recurrent problem of breakdowns at this point. The interviewees cannot remember when was the first time this occurred, but they indicate that they used a similar old copolene pipe to replace the damaged section. The last time this pipe broke in this section was on January 4th of 2018 (I will go back to detail this event later). In this occasion Collins provided a brand new pipe of the same characteristics (made of copolene with 63mm of diameter), which is expected to have a longer life period, and the neighbours keep the repair joints 1 and 2 since they were in a good state. The "Repair joint 3" was installed also to replace a section of the pipe that used to have leaking problems periodically. Here the passing of cars is considerably less and IN17, a Q11 resident living next to Repair joint 3, explains that the leaking problems occurred because the pipe was much deteriorated. This joint has not given problems since it was installed. The piece of pipe used to replace the one with leaks was again a second-hand one, unearthed from an area close by[44].

[44] This information was built by triangulating the testimonies of IN9, IN15, IN14, IN23and IN17.

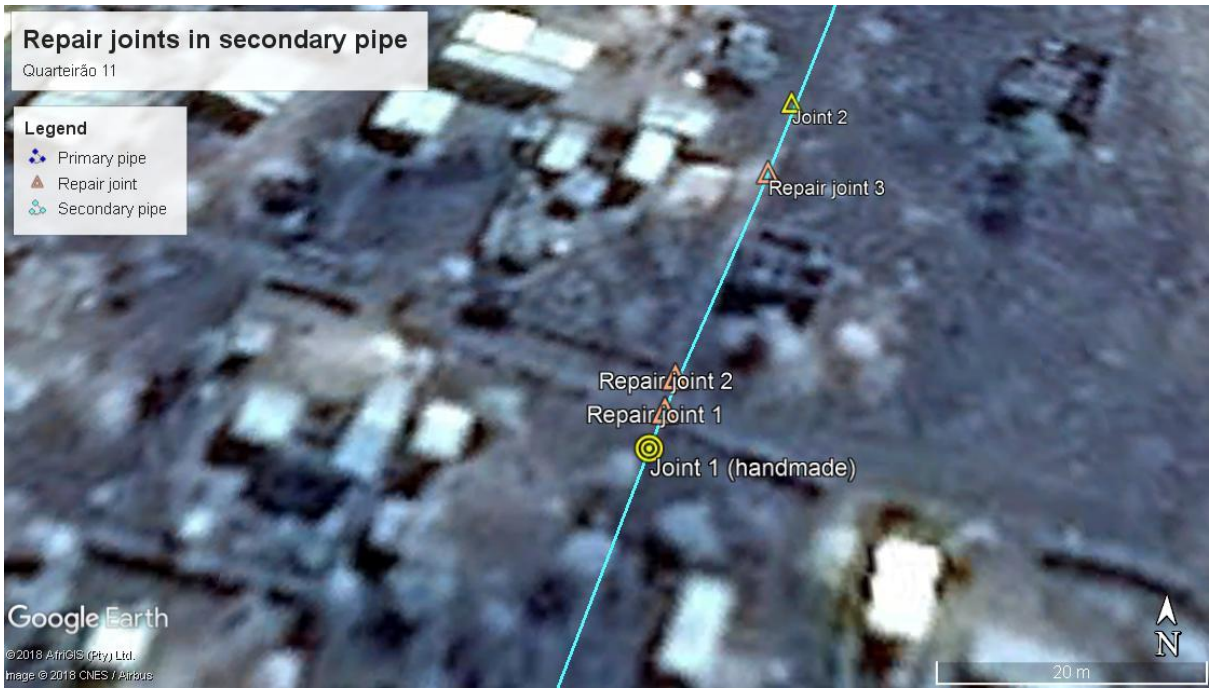

Figure 56: Repair joints in secondary pipe

Another change on secondary pipe was the extension made sometime later by the block boss of Quarteirão 3 (hereinafter Q3). The pipe used for this purpose have the same characteristics of the previous one: a copolene pipe of 63mm diameter, approximately 80m long (see in blue in figure 57). The aim of block boss of Q 3 was to install a water-tap in his house. To do so, he thought to replicate the strategy used by the neighbours of Q11. Namely, to remove sections of the "colonial" pipe he had saw buried on his farm, on the other side of the Estrada Velha. First, he talked to Q11 block boss to ask permission to connect his pipes at the location where the secondary pipe ended. The agreement then was that block boos of Q3 would be allowed to do so if he bought a new joint (joint 2 in figure 56) to replace a broken one that was producing a big leak. If the block boss of Q3 wanted to have water in his pipe extension he needed to solve this leak anyways, so he agreed. Then, he and his son cut and unearth from the farm 6 pieces of the pipe in order to facilitate its transportation. Then, block boss of Q3 bought 7 joints in order to put together the 6 pieces of pipe he unearthed from his pipe, plus one to replace Joint 2 in secondary pipe. In one day he and his son, without any help, installed the extension of the secondary pipe. After this, some neighbours of Q11 and Q3 asked to block boss of Q3 permission to make private connections in this extension[45]. He agreed without asking any money for that.

[45] According with the testimony of the interviewees, these houses were part of the group that did not participate in the installation of the secondary pipe, but the neighbours of Q11 refused to point them out.

Figure 57: The extension made on secondary pipe

The old pipes were removed from two areas (see in pink in figure 58): one next to Estrada Velha and the other some meters further in the other side of the road, in an area used by them as a farm. The neighbour says that these pipes are colonial, but Bairro Central secretary and a retired worker from the Railway Company said to me that they were installed by the Administrator Tefula, who was in charge of district government of Moamba between 2005 and 2007. This information was confirmed with personal of the current district government of Moamba (see the description of these pipes in chapter four)[46].

[46] Interview on Thursday 04.01.2018.

Figure 59: Original location of unearthed pipes

Figure 58: 63mm copolone pipe in the farm of the block boss of Q3.

Despite Collins recommend that the secondary pipes were buried in a depth of 50cm, the secondary pipe in Q11 and its extension is close to the surface: the erosion produced by the rain unearth some sections of pipe in different areas (see figure 60), revealing that the pipe is buried at just 10cm to 20cm 89epth.

Figure 60: Secondary pipe on Quarteirão 11

After some time, the leaking problems started in each one of the six sections of this extension in the secondary pipe. The biggest one was in front of household 1. The neighbours connected to this pipe got tired of repair it again and again and just stop fixing it. Soon workers from Collins notice the leaking problem in the area and closed valve 16 in the general pipe in Estrada Velha. All the neighbours of Q11 were affected and started to complain with block boss of Q3, demanding him to close this section of the pipe. The social pressure was big and sometime later the son of block boss of Q3 closed the pipe. They also were prohibited by Collins to put another old pipe. If they want a pipe there, they should buy a brand new one. Block boss of Q3 cannot afford a new pipe and this is why currently their water-tap is dry and they need to buy water from neighbours. The clousure of this section of the pipe also affected households 1, 2 and 3 of Q11 (see figure 61). These people had to invest money in extending their own 25mm pipes to get connected to the secondary pipe again. The further the houses from the secondary pipe, the greater the amount of money invested.

Figure 61: Households affected by the closure of secondary pipe extension

6.3.3. How the secondary pipe works

The functioning of the secondary pipe in Q11 can be described in terms of daily water flows schedules, water pressure problems, regular breakdowns, and water quality. I will address these factors in that order. As described in section 5.1, when there is no problem affecting the water supply service in Moamba, the valve that open and close the water flor from the distribution centre to the distribution network of the village is opened at 06:00 hrs. In normal conditions, during the rainy season, it takes water two hours to reach the area of Q11. This means that at 08:00 hrs residents in this neighbourhood are able to get water directly from their water-taps. However, during the dry season or during draughts, the pressure is usually not enough to make water flow in Bairro Central. To solve this problem, from 10:00 to 15:00 hrs the operators closed valves 0, 2, 3, 4 and 5 completely, concentrating all the water flow towards this neighbourhood. At 18:00hrs Moamba's water distribution network valve in the distribution centre is closed to deliver water to Pessene only.

The measure of closing the valves ensures that Bairro Central residents have water flowing from their taps at least during that period. For this reason, most households have some of their members engaged in the task of storing water during these hours. According to my observations, children are the main responsible for taking care of storing water, and among them especially girls. When asking who take care of these activities during school time[47], the answer was this depends on whether the children are attending the morning or afternoon shift at the school. If they are in the morning shift, are the adult women who take care of this task. If they are on the

[47] This topic was addressed in interviews with women residents of Q11 with different ages and different household composition: IN27, IN29, IN18, IN25, IN11, IN10, IN12, IN26, IN30.

afternoon shift, the children are who take responsibility for it, which allows adult women to work on the farm. This shows how the water flows schedules partially inform the daily routine of people, in the sense that it is mandatory to occupy one member of the house in storing water every few days. The intensity of this activity depends on the water storage capacity of each household. Nevertheless, the same storing activity gives the water users some degree of independence in terms of organizing their daily activities. For example, if a person wants to wash their clothes before they have water in the tap they can do so because they have stored water.

In relation to the characteristics of the secondary pipe, stands out the fact that it is composed of several pieces of second-hand pipes, unearthed from their original location and buried again in Q11 few centimetres from the ground surface. Some of these pipe sections were more deteriorated than others, so one factor affecting the functioning of this pipeline is related to the state of its materiality itself, which make the pipe prone to frequent breakdowns. A second important factor is related to the very improvise way in which the secondary pipe was built. Some of the pieces of pipe were put together with proper joins, bought in hardware stores for this express purpose. But other pieces were put together with recycled materials that residents of Q11 have at hand (such as pieces of rubber of old ties and wires) using very rudimentary methods. A third factor is related to the location of secondary pipe: one of its sections crosses a street quite busy with vehicles of different types. Being exposed to the weight of these vehicles make this section of secondary pipe especially vulnerable to breakdowns (see Breakdown point 2 in the satellite image below).

The satellite image below shows four points of frequent breakdowns. According to the testimony of residents living close to these points[48], breakdown points 1 and 3 are fixed and do not give problems anymore. As mentioned lines above, in the breakdown point 1 some neighbours replaced a professional joint that used to have constant leaking problems with Joint 1 which is a hand-made joint. Breakdown point 3 also had constant leaking problems because this section of the pipe was much deteriorated. The neighbours remove this section and replaced it with another recycled old pipe. Breakdown point 4 was leaking during the time I was doing the fieldwork. When Collins operators check this point, they found that the cause of the leaking was a private connection: the valve that connects the private pipe to the secondary pipe was disconnected. According to the operators, this could happen because of the water pressure or because of the weight of a vehicle remove the private pipe from the valve.

[48] IN15, IN14, IN17, IN9 and IN23.

Figure 62: Points of frequent breakdowns in Q11

The Breakdown point 2 seems to be the more problematic section of secondary pipe since it suffers from breakdowns periodically. As mentioned, the cause seems to be the frequent passing of vehicles. During my fieldwork, I could observe a leaking problem at this point and how it was solved. In the following lines I will describe this process.

On Saturday 6th of January one of Q11 residents[49] detected this leak (see picture below). The neighbours living near to the point said that the leak started on Thursday 4th but nobody had a clear idea of the causes. IN17 said that it looks like a problem in private connections, but later one of Collins' technicians confirmed that this was not the problem. On Sunday 14, this technician was informed of the existence of the water leak by a co-worker responsible for take readings from the water meters in the private connections. The technician appeared in the site and after seeing that the water loss was important, he proceeded to close the Valve 16, interrupting the flow of water towards the secondary pipe. He explained that, in order to have a quick diagnosis of the problem, he introduced the hand in the mud and he found a hole in the pipe and no other problem with private connections. He advised some of the neighbours there that they needed to buy two new joints plus 1m of 63mm copolene pipe to replace the broken section.

[49] IN15 let me know about this problem in an informal conversation hold few days after she notice the problem.

Figure 63: Signs of a leak in Breakdown point 2 in secondary pipe

Ten days later on Tuesday 16, the same technician return to Q11 to dig in the area of the leak and confirm the problem in the secondary pipe. Once the pipe was uncovered he found that the cause of the leak was not as simple as he thought. At the beginning the thought that the leak could be solve by installing a clamp and a plug to seal the hole in the pipe. Then he realized the pipe had a kind of cracking line on one side, a kind of breakdown that highly probable was produced by the weight of the cars that pass continuously through this point. In consequence, it was necessary to cut the damaged section and replace it by a new piece of pipe. Then, he explained some neighbours the need to buy a piece of approximately 2 meters of a new 63mm diameter copolene pipe to replace the old one. The pipe should have this size in order to locate the joint out of the road intersection where the cars pass more often, preventing the occurrence of new breakdowns of this type. The Collins' technician also said to the neighbours that they could re-use the joints that already were installed, adding that there was a possibility that Collins helps them by providing some materials, but they need to show interests by digging to remove the old pipe and to install the new one.

Figure 64: Technicians of the water utility working on a secondary pipe breakdown

On Friday 19 of January, only 15 of the 25 neighbours connected to the secondary pipe helped to fix the breakdown. The rest could not participate because they were working elsewhere, however, some of them contributed with sand required to cover the pipe as a measure of protection against rocks and other hard objects that could damage it, before burying it again. The neighbours started digging at 08:30hrs and after a while, two Collins technicians arrived bringing the new 63mm diameter copolene pipe provided by the company. They were in charge of open the joints and remove the old pipe. Also in charge of installing the new pipe, which required to use heavy wrenches and the help of the neighbours. The joints in the old pipe were in good estate, reason why they were re-used to install the new pipe.

Figure 65: Neighbours of Quarteirão 11 working on repairing the secondary pipe

All the neighbours present at that moment participated actively in the works, showing in a sort of performative act, their interest in being seen doing their parts of the work. This is interesting in different ways. First, the fact that water users need to periodically invest labour in order to renew their property over the secondary pipe resembles a situation commonly present around

irrigation channels in rural areas, where the hydraulic property is created based on collective action, but not often documented in contexts of drinking water supply infrastructure. This behaviour turns my gaze back to the work of Anand (2011), where he tells us that hydraulic citizenship is something precarious that demand constant reconfirmation. In this case, the reconfirmation has to be obtained from the rest of the water users that collectively own the pipe. Each household needs to update the recognition of the rest of the neighbours that they have made themselves worthy to continue using the pipe. And at the same time, the reconfirmation of this hydraulic right have to be obtained from the utility company, which can cut the water flow towards the secondary pipe if the water users do not guarantee that they will prevent water to be wasted by keeping the secondary pipe in good conditions.

Here is another detail that draws my attention. When the technicians from the utility company arrive at Q11 to fix the pipe they demand, on behalf of the company, an investment in labour and materials. This rise some questions about the type of property embodied on the secondary pipe and the consequences that this brings in terms of who is responsible for the maintenance of the pipe. Where the duties of water users end and where the duties of the utility company start? The story of the pipe repair process that I have presented above shows that the pipe took 13 days to be fixed. Noticing the leak for the first time, the neighbours did not notify the company, because they knew that if they did, the company would send workers to close the flow of water in order to avoid wasting the resource. Once the company personnel noticed the leak, the water flow towards the secondary pipe was closed, but they did not take any additional measures to fix the breakdown. The neighbours also had no initiative to fix it until their water reserves were completely exhausted. Only when this happened they coordinated among themselves and with the utility company and agreed on the date to carry out the works. Since the state of the pipe is an important factor in terms of keeping a healthy water quality, developing a better understanding of the pipes installed by the neighbours is very important in order to develop adequate institutional frameworks to carry on with this maintenance task.

From my perspective, the difficulty to give proper maintenance to the secondary pipe lies partially in the nature of the property itself that the pipe embodies. The owners can prevent others from using this conduit by saying that only those who worked in its installation and those willing to pay for the right to be connected can use it. In this sense, it looks like we are facing a good under a collective regime of private property. But precisely because the pipe is collectively owned, it is not easy for its users to deal with the risk of free-riders. In consequence, while everybody demands to equally receive a good water supply when it is needed to fix the pipe nobody want to be the first in participating in the task because of the personal resources investment that it demands. The individual duty of each household seems to be diluted in the crowd. On the other hand, the utility company does not take the initiative either, despite it is charging monthly water bills. It is possible to argue that they are not free to intervene in the secondary pipe since it is a private property of the neighbours, however, it is clear that leaving all the responsibility of the pipe in hands of the users plays to the benefit of the company, because in this way its costs are reduced.

To finalize this section it is worth noting that the layout of the secondary pipe in Q11 produce a spatial differentiation between its residents. This happens because the households located nearer from the pipe are the first in receiving water every time the flow of water is restarted. This fact matters particularly in contexts of protracted cuts in the water supply service. When

this happened, water users start to consume their reserve of water and, if the cut in the service is too long, residents of Q11 have to face a very difficult situation of water shortage. When the flow of water is restarted, there are very few houses that receive water first, while the rest have to wait. Then, the houses without water in the tap will ask for water from those who do. I develop the consequence of that this spatial differentiation has on residents of Q11in the next chapter when addressing the role of water infrastructure as a factor of social differentiation.

CHAPTER 7

The water infrastructure of the households: connected vs. disconnected houses

The present chapter is aimed at analyzing the role played by the water infrastructure used within the houses of Q11 in shaping social relations among the neighbours and inside the households, as well as in the emergence of particular arrangements to share the water infrastructure between houses with and houses without water-tap. As I attempt to show, water infrastructure also socially differentiate residents of Q11 in various ways: spatially, in the sense of determining who has water in contexts of protracted cuts in the water supply service and who does not; and in terms of water security, by determining how much water can each family consume per day. The evidence presented is the product of analyzing data collected through interviews and systematic observation in 25 of the 60 houses that compose Q11. Among the 60 households that compose Q11, I could identify 6 of them without a water-tap connection (see these households in red in Figure 66).

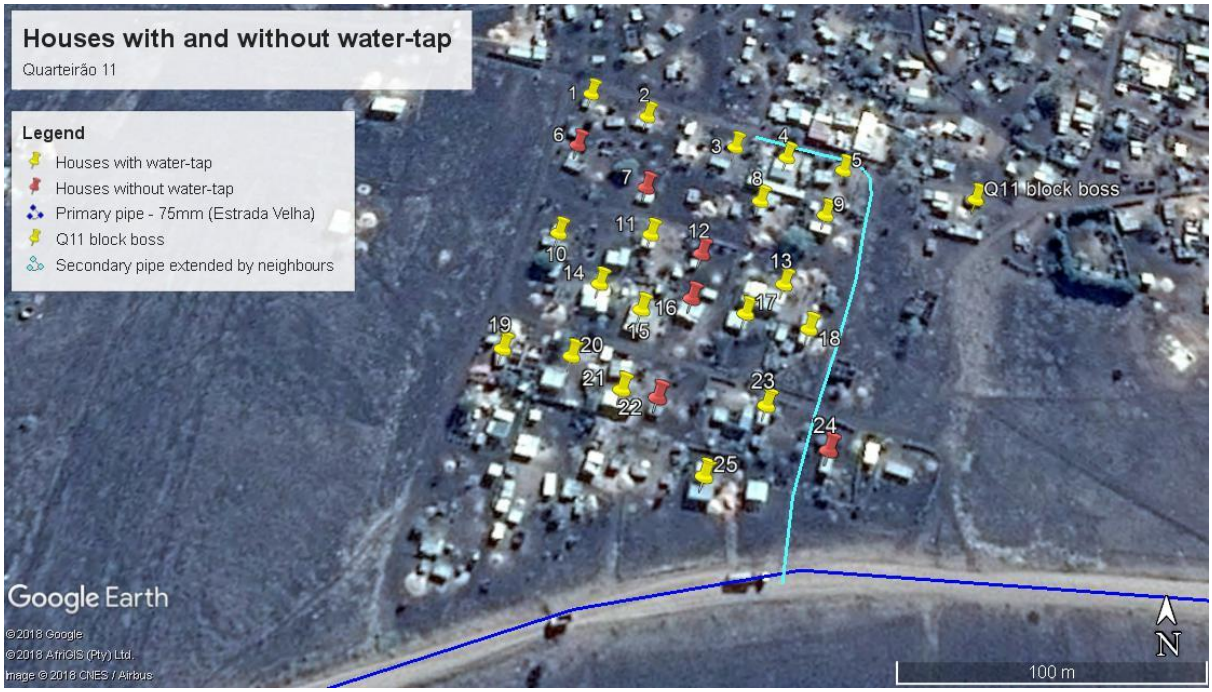

Figure 66: Households with and without water-tap connection

7.1. The role of domestic water infrastructure in shaping social dynamics in Quarteirão 11

Among the six houses without water-tap connection, I was capable to establish contact with five of them. Among them, households 6, 7, 16 and 24 pay monthly for water a flat tariff of 5MT per 25lt of water to another neighbour. Household 22 shares equally the water bill with household 21. This arrangement gives members of household 22 the freedom to use the water tap whenever they need without asking for permission. Paying attention to the characteristics of these households I noticed that having a water tap connection is related with the composition of the households and the stability of their incomes. In the first place, four households are composed of single women at different ages living with children, and in one case with grandchildren. The fifth household is composed of a single man visited from time to time by two daughters and one granddaughter. So, in general terms, it seems like especially households composed of a single adult with children are those that do not have a water-tap in Q11. Households with water-taps on the other hand, usually have, or has had recently, more than one member contributing economically to the house (usually both parents). And among those with only one economically productive member, usually this person have a formal or stable job.

Table 5: Characteristics of households without water tap in Q11

Household	Composition	Water access arrangement	Source of income
6	57 years old single woman and 17 years old son.	Buy water from neighbours paying monthly a flat tariff: 25lt per 5MT	Small family farm Solidarity of the neighbours Sporadic jobs performed by the son.
7	Single mother, (approx. 40 years old) and 16 years old daughter.	Buy water from neighbours paying monthly a flat tariff: 25lt per 5MT	Family farm Daughter charge for braiding other women's hair.
16	Elderly single woman and two grandchildren (13 and 16 years old).	Buy water from neighbours paying monthly a flat tariff: 25lt per 5MT	Sales of firewood collected every day near to the river.
22	36 years old widow and two daughters and one son (16, 14, and 9 years old respectively).	Share equally water bill with household 15.	Sale of peanuts in Maputo city.
24	Single man	Buy water from neighbours paying monthly a flat tariff: 25lt per 5MT	House builder.

Among the household without water-tap, household 22 is the only one that shares the water bill with the next-door neighbour. This is an important difference because this arrangement give to the members of this household the opportunity to consume a variable amount of water per day. The establishment of this particular arrangements is explained partially by the fact that the income of the mother of household 22 is more stable than the rest of household without water-tap, but also because of the personal friendship relation among the mothers of households 21 and 22.

The two types of arrangements, however, are perceived by the members of these six houses as part of a dependency relationship. According to the testimonies of the members of household 22, even despite they share equally the water bill with household 21, they feel that the owners of the water-tap can change their minds and demand them stop using the tap. The others households also fear that the neighbours from whom they buy water refuse one day to continue selling them water. They do not feel free to disagree or have an argument. They need to keep a good relationship with them and for this reason, this relationship is perceived as a kind subordination. For this reason, even the household that has free access to the water tap, feel the need of keeping a water stock all the time. They have 5 water drums of 25lt and 5 of 20lt. They try to keep always at least 3 drums full (see Figure 67). However, this also can be interpreted in a different way: the act of sharing the water-tap function as a factor that prevents the emergence of protracted conflicts between these two households. The two families are very close and share not only water but also food and help each other in doing the domestic chores.

Figure 67: Detail of plastic drums to store water in a household without a water-tap

The installation of in-home water-tap connections has had also an important impact on the relationships inside the household and on the living conditions of its members, particularly of women and children. Before the installation of these private connections, in Q11 women used to weak up at 03:00 or 04:00hrs to go to the closer standpipe to buy water. The reason why they went to the standpipe at that time was the number of people attending this point. The line was

long and the chances of filling all their water drums were higher if they arrived early. This also led women to try to fill as much water drums as possible. Some of them use 10 drums (25lt each) every time they buy water, to avoid the need of going back again the next day. Of course, this means several travels to transport all the plastic drums to their houses[50]. IN29's account sums up fairly well the general experience of Q11 women in relation to this activity. According to her, she used to weak up at 03:00hrs. At that time she left for the standpipe and left one of her plastic drums marking her position in the queue. Then, she goes back home to sleep for an hour. At 04:00h she left again for the standpipe, but this time with her 3 years old daughter on her back, because she had no one to leave her with. At that time the father also went out to collect firewood to sell it as fuel. Some days, there were so many people in the queue that when her turn came it was already 14:00hrs and she only managed to fill a drum because the standpipe closed. After this, she goes back home to start doing the domestic chores.

With the in-hose connections several things changed. In the first place, IN29 mentioned that she and her family were able to access more water per day, which eliminate the need to prioritizing some water use practices. These prioritized practices were drinking, cooking and bathing. Other activities like washing clothes and washing the dishes were reduced in frequency, which had a direct impact on the way people treated them. IN29 mentioned that once, her daughters were returned from school due to lack of personal hygiene. That day they wore dirty clothes and had not taken a bath. From then on, the girls missed class every time they could not wash their clothes. Something similar was pointed out by IN5, a resident of Quarteirão 4 to highlight the importance of bathing in Moamba: *"it is very difficult to find a* [romantic] *partner if a person is accustomed to walking with dirty clothes or without taking a bath"*[51]. The availability of water in the house also allows building bathrooms with septic tanks that require the use of water. Before this, they have latrines that work well during the dry season but when the rain arrives, the instability of the soil produced that the latrines collapse. In consequence, during the rainy season, they used to practice open defecation and build a new latrine once or twice per year.

During the interviews about the conditions of water provision before the installation of the water-taps, I found remarkable similarities to what was found by Van Houweling (2016) in her research about gender roles and water practices in the northern Mozambican region of Nampula. For instance, the fact that there is a word that appeared almost in all the testimonies: suffering. There was a physical suffering produced by the effort to transport several times per day the weight of 25lt drums in the head[52]. But also physical suffering produced by the deprivations derived from the need of reducing the amount of water consumed per day. The emotional suffering was related to feelings such as shame, because of not being able to take care of their personal hygiene like other people did. And feelings of guilt, feeling suffered particularly by mothers to see that their children did not attend school for helping them, or simply for not being able to spend more time talking to them: after all the physical work they do, women needed to rest. IN29 also mentioned that her husband used to fear that she could use the darkness of the

[50] The reconstruction of the activity of buying water in the standpipe is based on the testimonies of IN29, IN27, IN4 and one man, IN24, who in the absence of his wife, was the one who told me how they experienced this period.

[51] Interview with IN5 on 14.12.17.

[52] The closer standpipe was approximately 237m away from Q11 and women start caring water as soon as they are 5 years old (they start with small amounts of water).

night to meet another man each time she went out to buy water at the standpipe. This situation change with the water-taps. However, since every case is different, it is not possible to say that the relations between men and women improved with the arrival of water-taps. Which is clear, is that the installation of water-taps in the neighbourhood allow women spent more time engaged in recreational activities with their families and their friends, and improve their living conditions and their relationship with their children.

7.2. Domestic water infrastructure as a factor of social differentiation

Water infrastructure plays a role in the dynamics of social differentiation in different ways. The absence of a water-tap is by itself a sign of a lower social status because means that people living in that house has not the minimum resources required to afford the installation of the tap and the monthly water bill. As I mentioned earlier, this has a correlation with the situation in Q11, in which households without a tap are those composed of single adults with a burden of children who have not yet reached an economically productive age. As a result, they are not able to generate the necessary resources to buy the materials for a private water connection. On the other hand, it was interesting the kind of answers I receive when asking why the owner of house 24 (see in Figure 66) has not a water tap when the secondary pipe pass literally through his property. He does not even need to invest much money in a 25mm pipe in order to get connected. Independently of how well my interviewees know this person, it is significant that they attribute the absence of the water-tap to personal characteristics such as having no "planning capacity", being a "not responsible" person, or remain "without interest in progress". This means that water-taps are not only interpreted in terms of the socio-economic situation of people but also in terms of personal attributes and character.

Another way in which having a water-tap at home affects the way people perceive others in Moamba, is related to the fact that in-home water-tap connections facilitate the daily activities of personal hygiene. As I mentioned, personal hygiene has an important meaning for the social relations in the town. The water-tap also make easier to build and expand houses made of cement, since water is an essential part of the cement brick production process. Cement houses are another indicator of social status because having a cane-made house not only indicates a situation of scarce resources but also is associated with "uncivilized" socio-cultural values. The statement of one of the operators of Collins infrastructure summarizes well what has said in informal conversations: *"Before it was normal to live in these houses. People did not give such importance to hygienic conditions. They did not have the idea of leaving something for the children. They thought*: *why I am going to spend on something that I will not enjoy anymore when I die? Now everyone wants to improve, to progress"*[53]. In summary, water-taps are correlated with people's capacity to buy things; with personal hygiene; and indirectly with cement houses, all important in terms of social differentiation.

Along with water-taps, tanks are elements that make certain households stand out from the rest. In contexts of interruptions in the water supply service, households with these tanks become points of reference to which both, neighbours of Q11and residents from other neighbourhoods

[53] Informal conversation with IN33, November 15th.

go to buy water. Given that it is the owner of the tank who chooses who sells water or not, the existence of these tanks provides the basis for the development of solidarity bonds between households. Especially when it comes to a prolonged cuts in the water supply service, in which the act of selling water can put at risk the water security of the tank owner itself, the basis for the emergence of solidarity bonds lays on the fact that the tank owner is doing something for the person that is asking for water. Eventually, this person will find the opportunity to "pay off the debt", and it will be establish a relationship that goes beyond the mere periodic transaction of purchasing-selling of water. For instance, household 19 have a $1m^3$ tank filled with water all the time, but they do not share this water with anybody because is their buffer in contexts of water scarcity. Household 20 has an $8.32m^3$ cement tank, but only share water with their relatives and do not charge them for this water. The only household in Q11 that sell water to any person requesting it is household 9 (see Figure 66). They sell water at a price of 5MT per drum of 20 or 25lt.

Something similar happens as consequence of the fact that the location of the houses in relation to primary and secondary pipes determine who houses have water first when the water supply service is re-started after a prolonged interruption. In one of the several occasions in which this situation happened during December 2017 and January 2018, I noticed that houses 22 and 23 receive water in their taps before everybody else, and children from houses 14, 15, and 16 were fetching water from house 22 water-tap. Later, the child from household 14 explained that it can take some hours before the water start flowing from his water-tap. They could not wait because their water reserves were already run out by then.

7.3. Domestic water storage infrastructure and the water security of the families

As mentioned before, in normal conditions the residents of Q11 have water in the taps from 08:00hrs to 18:00hrs. During the dry season and context of draughts, the water supply in this neighbourhood can be reduced to five hours per day, between 10:00hrs to 15:00hrs. But the interruptions in the water supply service are frequent in Moamba, they have an indeterminate duration and their occurrence is, to a great extent, unpredictable. Because of these factors, even residents with in-home private connections are forced to store water every few days. These conditions have defined the components of the domestic water infrastructure used by most households in Moamba to store water. Based on the inventories elaborated during my fieldwork, I identify that the basic water storage kit in Q11 is composed by two types of recipients: 1) plastic drums and buckets of 20lt and 25lt, used not only to store water but also transport water from the fetching point to the house for example; and 2) drums with an average capacity of 210lt, located inside of the house, usually in the kitchen. The water stored here are commonly reserve to drinking, cooking and wash the dishes. For other practices as washing clothes and bathing people usually use water stored in plastic the 20lt drums. To this basic kit some household add water tanks. Household 19 for instance have a $1m^3$ plastic tank, while households 20 and 9 have cement tanks of $8m^3$.

Figure 68: Domestic water storage infrastructure

During my fieldwork the rains were irregular and soon people started talking about the presence of a drought. During January 2018, water level in the river started to decrease faster. The fall in the water table causes the amount of water injected into the water supply system to be reduced, reducing in turn, the water pressure in the system. For residents of Q11, this meant that instead of having water from 08: 00hrs they had it sometimes at 09: 00hrs, others at 10: 00hrs when the operators close specific valves to concentrate the flow of water towards Bairro Central (see chapter 5). When the drop in the water table is pronounced, the pumps in the intake station are not able to inject water into the system. In consequence, a general water shortage is produced in Moamba. This happened from January 21st to January 25th. For Q11 residents connected to the secondary pipe, this cut in the water supply service came at the worse moment. Because of the breakdown in the secondary pipe described in chapter 7, they had already had a water shortage from January 14th until January 19th. This means that they only had 2 days in between to refill their water containers. In consequence, households with a limited financial means, small labour force, and reduced water storage capacity were badly prepared to face the second shortage.

From January 22nd to January 28th[54]. I conducted a small survey to collect data aimed at identifying the factors affecting the number of litters of water consumed in the households in Q11 when cooking, bathing, washing the clothes and washing the dishes. Unfortunately, the sample size selected for the observations does not give a statically representation of the population. Using Cochran formula I determined that the sample size for households without water tap should be 4.1 and for households with water-tap 9.1. The conducted surveys without missing data were 4 for household without water-tap but only 4 for households with water-tap. However, it was useful to notice that water-taps are not the main factor in determining the amount of water consumed by each households[55]. There are other factors such as their purchasing power; the number of the household members; the available labour force to fill and transport water containers; and their water storage capacity. In the next paragraphs, I will try to show how all these factors affect the situation of water security of residents of Q11. Based on the data collected through these survey, I took an average of the water consumed per day, per person in each of these households. This information is presented in tables 6 and 7.

Table 6: Water consumption per day per person. Households with water-tap

HOUSEHOLDS WITH WATER-TAP					
Household 3 Water Storing Capacity (Lt)				Water consumption / person/ day	Household members
Drum	260	1	260	8.6	7
Drum	20	5	100		
Drum	25	1	25		
		TOTAL	**385**		
Household 4 Water Storing Capacity (Lt)				Water consumption / person/ day	Household members
Drum	210	2	420	8.6	5
Drum	20	10	200		
		TOTAL	**620**		
Household 19 Water Storing Capacity (Lt)				Water consumption / person/ day	Household members
Drum	210	1	210	24.6	4
drum	20	1	20		
drum	75	1	75		
drum	25	1	25		
Other	36	1	36		
Other	20	3	60		

[54] In Mozambique the rainy season goes from October to March or April.

[55] Those who are having an in-home water connection pay less for water: Collins charge 0.02MT per 1lt consumed, while at buying water from a neighbour is 0.2MT per 1lt. This of course in combination with the purchasing power of the household affects the water they are capable to buy.

tank	1000	1	1000		
		TOTAL	**1426**		
Household 14 Water Storing Capacity (Lt)				Water consumption / person/ day	Household members
bidon 25lt	25	3	75	16.5	6
bidon20lt	20	3	60		
baldes 25	25	2	50		
ceramic 25	25	2	50		
		TOTAL	**235**		

Table 7: Water consumption per day per person. Households without water-tap

HOUSEHOLDS WITHOUT WATER-TAP					
Household 16 Water Storing Capacity				Water consumption / person/ day	Household members
Drum	20	1	20	19.1	3
Bucket	20	5	100		
Bucket	5	4	20		
Drum	75	1	75		
			215		
House 7 Water Storing Capacity				Water consumption / person/ day	Household members
Drum	20	3	60	19.7	2
Drum	25	1	25		
Drum	50	1	50		
			135		
Household 6 Water Storing Capacity				Water consumption / person/ day	Household members
Drum	210	1	210	18.1	2
Bucket	20	2	40		
Drum	20	4	80		
Other	80	1	80		
			410		
Household 22 Water Storing Capacity				Water consumption / person/ day	Household members
Drum	25	5	125	17.7	4
Drum	20	5	100		
Other	30	1	30		
			255		

The data collected shows that households with water taps do not necessarily consume more water than households without water-tap. This fact could be related with the financial resources owned by each household, the number of its members, their ages and gender. The financial resources can limited the amount of water each household can afford by month, while the number, the ages and the gender of the households' members are related to the availability of labour force to fill the water containers. As I have showed, the tasks of fetching and storing water, as well as the main domestic water use practices are female tasks. All these factors seems to work in the cases of households 3 and 4. These households show the lowest water consumption per person per day. On the other hand, they also show a number of household member higher than the average of the sample. Household 3 is composed by both parents and five children; but the father works in South Africa and is absent most part of the time, and the oldest child is a 14 years old girl. The rest of the children are between 1 and 7 years old. Household 4 is composed by a five people. She was sick during the survey, their children are under the age of 10 and the father was absent.

The data collected also shows that the water storage capacity between households in Q11 can vary as much as going from 125lt to 1,426lt. In practice, the difference is even larger, since the two households with cement tanks (households 9 and 20 in Figure 66), which have a capacity of 8,320 litters, are not included in this sample. Household 19 not only have the larger water storage capacity of the sample (1,426lt.) but also shows a greater signs of material wealth: a cement house bigger than the rest, with better materials, several pieces of furniture, satellite TV connection and one car. The mother is a housewife but the father has a formal job in the government as a school teacher. The opposite situation is represented by household 6 and 16.

These households have a water storage capacity of 410lt and 215lt respectively but their labour force to fill all their water containers is limited. Household 16 is composed of two people: one woman about 60 years old with a chronic injury due to an accident that has affected her physical abilities, and a 17-year-old son who is not always present at home. Household 6 is composed of one elderly woman and two grandchildren: one 13 years old and the other 16 years old. During the day, both children spent a lot of time out of the house, attending school and spending some days at the mother's house. Additionally, neither of the two households have a stable income source. However, by comparing the amount of water consumed by these two household with the water consumed by the rest of households in the sample, it result clear that households 6 and 16 water consumption is not the lowest in the group. This could be explained in terms of the solidarity bonds that these two households have built in Q11. When the neighbours talk about the history of these two women they highlight that they have been marked by fatality and they feel compassion for them[56]. For this reason they try to help them as far they can, sometimes not charging them for water or providing them food. In this sense, the survey shows that their water access is not the worse in Q11 but this does not eliminate the fact that these two households depend to a great extent on their neighbours, which also constitutes a form of vulnerability.

[56] The neighbours mention they are not only are lonely women (without husband or other relatives) but one has suffered an accident and to the other an illness snatched the son who used to take care of her. She has another son but he has completely abandoned her. To make matters worse, her daughter-in-law denies taking responsibility for her children.

Finally, I would like to present the description of how members of household 14 collected water from the tank of household 9 during the context of water shortage suffer in Q11 from January 21st to January 25th of 2018. In this way I pretend to reflect the importance labour force availability have in accessing water and to illustrate how this practice is strongly marked by gender. Currently, the alternatives water sources for residents of Q11 during these water shortage contexts are the private water tanks of other residents and, when these people are not able to keep selling their stored water, the cistern cars that sell water collected directly from Incomati River. The formers sell 25lt of water for 5MT. The latter sell the same amount of water for 15MT. During the water shortage context mentioned above, I could observe how members of households 14 collect water from the tank of household 9. Household 14 is composed of an elderly couple and four of their grandchildren, who took advantage of school vacations to spend time in Moamba with their grandparents. The grandmother orders their 13 and 14 years old granddaughters to buy water in the mentioned household, despite the 16 years old grandson was equally available at that moment. Using two wheelbarrows, the girls transported four 20lt drums towards the water tank. They pay 5MT per drum. The task was evidently hard for the girls, especially when they had to withdraw the bucket from the bottom of the tank using a rope. Then they poured water from the bucket to the drums using a funnel made of an old plastic bottle (see Figure 69). According to the older grandson in the house (16 years old) looking for water is by far the most difficult task they have to do because they never know if the first house they visit will give them the water. Sometimes they have to spend a lot of time walking around the village looking for a house with a tank that wants to help them. This can give an idea of the difficulties that these water shortages can bring for households in Q11.

Figure 69; Girls fetching water in Quarteirão 11

CHAPTER 8

Discussion and conclusions

In this research I have tried to answer what water infrastructure is and what it does in terms of shaping everyday practices and social dynamics. In relation with the former question, and based on the empirical evidence collected during my fieldwork, it can be stated that Moamba's water infrastructure is an ensemble of sociotechnical artefacts, devices that have been put together to produce drinking water and distribute it to their inhabitants. But this thesis shows how infrastructure is not only pumps, valves, pipes, tanks, cement, PVC, galvanized iron and biochemical processes. In order to function, Moamba's water infrastructure needs to be part of a system that connects particular forms of social coordination of labour (the utility company, the collectives of neighbours, governmental institutions are manifestation of it), institutional frameworks of norms and bureaucratic rules that shape the administration of the water sector in Mozambique, as well as practices, values and norms shaped by broader economic and socio-political systems. Water infrastructure also exists in a discursive dimension. For instance, the current discourse in Moamba says that all its residents have the same right to access the drinking water produced by this infrastructure. However, the condition to have this right consist on being a customer who pays monthly to the company that provides the water supply service, which functions as a mechanism of segregation based on the socio-economic situation of people.

Since the purpose of my research is to push the understanding of water infrastructure beyond its pure materiality, I have tried to show how water infrastructure acts, and how it affects and is affected by other components of the socio-technical system in which it is embedded. This does not means that I am focused on formulating a more precise definition of water infrastructure. Using a socio-technical definition of water infrastructure as presented above, is useful as starting point, but is important to notice that all definitions are necessarily limited, in the sense that they are per definition a simplified model that aims to capture inherently complex processes. In this sense, definitions are political statements that, consciously or not, impose one particular view over others. Ultimately the purpose of my research is not to come up with a new definition that suggests what water infrastructure should be, but to explore how a socio-technological ontology of water infrastructure, and in particular the concept material agency, can help to explain how processes of change are happening around it and what the role of infrastructure is in these processes.

This is the reason why answering what water infrastructure is means answering how water infrastructure is built, how it emerges in time and space, and what it helps doing. By answering these questions one of the first findings of this research confirms that water infrastructure is strategic because at least partly, it is the product of planned actions aimed at fulfilling specific goals and interests in the long-term. Water infrastructures is partially controlled by political as well as engineering objectives: engineer are focused on optimizing the functioning of the water supply system, trying to find the most efficient way to deliver specific amounts of water to specific areas, with a particular water quality, in a specific time and frequency, etc. While

political objectives are aimed at producing particular outcomes in terms of differentiated access and distribution of resources, which usually is associated with the pursuit of long-term goals of particular elite/historically advantaged groups. This thesis analyse both strategic dimensions of water infrastructure and provides evidence that supports the idea that, indeed, water infrastructure contributes in reproducing the uneven power relations in society (Rodina and Harris, 2016; Anand, 2011; Truelove, 2011; Kooy and Bakker, 2008; Swyngedouw, 1997).

By explaining the different types of changes registered in Moamba's water treatment and distribution system between 1962 and 2016, I show how during the colonial time, Moamba's water infrastructure was used to create a differentiated hydraulic citizenship (see also Anand, 2011). On the one hand, the water infrastructure worked as a mechanism for racial segregation, built to provide drinking water to the relatively small Portuguese population through in-house piped connections, while the vast majority of the Mozambican population remain in a very precarious situation when accessing water. Most of them depended on the goodwill of Portuguese households who wanted to sell them water. The alternative way to access water was through long queues at the few public taps that existed in Moamba at that time; to use wells of salty water; or to go to the river to catch water directly without any kind of treatment. On the other hand, the colonial government created two categories of Mozambican citizens: those who decided not to fight the colonial occupation were allowed to access drinking water through one public standpipe located in Bairro Indígena. This entire neighbourhood was built for this privileged group of Mozambicans with small cement houses that resemble those of the Portuguese people. In addition they receive the opportunity to work on the colonial railway company and to send their children to school.

Later, with the independence of the country in 1975, the water users went from depending on the Portuguese government to rely on the district government for water service provision. The new political purpose of the water infrastructure from now onwards was to provide drinking water to all Mozambican citizens, making, at least in theory, no distinctions. This implied the need for the increase and improve the capacity to treat and distribute water. In concordance to this, the changes implemented in the infrastructure during this period has included periodic extensions on the water distribution network, going from approximately 5 km of pipes during the colonial times to 36km nowadays, and the increase in the number of public standpipes, going from 1 to 29. However, I show in this research that in practice these changes have not meant water for everyone. Moreover, the problem is not just that the water distribution network does not reach all neighbourhoods (the current coverage is 56%), it is also the fact that the quality of the service is not the same for all. In other words, despite today the access to drinking water is no longer based on racial segregation, there is a spatial pattern of social differentiation that still persists in Moamba. In theory all inhabitants of Moamba have the same right to access piped water, but the water supply service is provided by a private utility company aimed at achieving financial sustainability and making profits. As consequence, the access to piped water is conditioned by the capacity of each family to afford a private connection and to pay the monthly water bill. Hence, it is not by chance that the poorest zones in Moamba, such as Bairro Central and Matadouro, are also the areas with the worse water supply service.

The data collected in the process of zooming into one of these disadvantaged neighbourhoods, Bairro Central, has shown that in these processes of social differentiation there is space for contestation. The most recent development in Moamba's water supply system has been shaped

by the decision of the Mozambican government of giving the administration of this water infrastructure to a private company. Soon later of having assumed the operation of the infrastructure, the top management of the company decided to close down all the public standpipes. Nevertheless, in the case of one particular standpipe, this order was (deliberately or not) ignored by the technicians of the water utility company. By keeping this standpipe in function and hidden from the sight of the utility company, the residents of this neighbourhood fight the control that this company exerts on the water infrastructure, and by doing so, also fight the new neoliberal paradigm promoted by the government in which all Moamba's inhabitants, in order to achieve hydraulic citizenship, have to become responsible customers that pay punctually their water bills. The conclusion extracted from this historical analysis of Moamba's water infrastructure is similar to the findings of Kooy and Bakker (2008) who researched the colonial and contemporary water supply infrastructure in Jakarta and state that: *"... contested and evolving process of social differentiation are linked to the differentiation of water supply infrastructures and of urban spaces*" (Kooy and Bakker; 2008: p. 1843).

The novelty of my work is to provide evidence that supports the thesis that water infrastructure is not only the outcome of strategic processes but at the same time also pragmatic in nature, since it is produced to a great extent by actions aimed at solving everyday challenges in an ad-hoc and improvised way. The practices presented in Chapter 6 by which the water users tinker with the infrastructure to extend the distribution network; to install their private pipes; in some cases fixing the pipes with materials they have at hand, et cetera, are a good example of this. All done through experimental and very rudimentary methods in order to solve everyday challenges. However, this research shows that the practice of engineers, operators and construction workers does not escape from this pragmatism either.

In Chapter 5 I show in detail how the built infrastructure does not mirror what is specified in the design map. According to Collins' general manager and two construction workers[57], these deviations respond to the need of adapting the design to the several changes occurred in the physical and institutional environment of Moamba between 2008 when the original design was presented and 2013 when the construction project was finished. Among the main reasons for the deviations they highlight the cuts in the original budget approved for the project; the unforeseen rapid population growth, which made necessary to increase the number of projected pipes; the change in the shape of the streets and the spatial disposition of the houses. This last reason referred to the fact that at the location of the pipes on the design map the construction workers found new houses that they had work around and it other places they noticed that the streets were too narrow and the heavy machinery used to install the pipelines did not feat in. The interviewed construction workers also mentioned that some details of the design were modified because the shape and materiality of small pieces of infrastructure (accessories as joints and elbows) did not allow them to follow exactly the design.

To the fact the process of water infrastructure development is to a great extent pragmatic, we need to add that infrastructural functioning is largely contingent: not even the engineers that design the infrastructure nor its operators can predict with complete certainty how the infrastructure will behave in particular environments, and what will be the outcomes of its functioning. In this sense, I concur with Pickering (1993) that infrastructure is emergent in time

[57] Interviews with Collins' general manager on 31.01.2018 and with Claudio and Gildo on 05.01.2018.

and space because it is unknown what kind of things it will do until it starts doing them. Taking this into consideration is highly important to our understanding of water infrastructure since it shows that its making and operation is an experimental process, governed to a great extent by a logic of trial and error.

I started to delve into these different unforeseen ways in which the infrastructure works after I noticed that the operators in Moamba are immersed in a perennial fight to make infrastructure works properly. In this fight, the operators not only have to deal with constants breakdowns in different parts of the system. They also have to daily operate specific valves to force water flow towards the intended direction. One of the areas where water resists to flow is Bairro Central. I soon discovered that the main problems in this neighbourhood were originated by one major modification in the original design map. According to the 2008 design map, the water distribution network in this neighbourhood would be connected with the rest of the network in the north by an underground pipe that crosses the railway close to the train station. As I explained in section 5.6, this pipe was not needed to be longer than 150m and it would be a more efficient way to supply water to this neighbourhood. However, because a lack of understanding between Conduril and the Mozambican railway company CMF, this pipe was deleted from the original design and was decided that instead, water will be conveyed to Bairro Central throughout a pipe that travels a distance of approximately 17 times longer than the pipe projected in the first place, partly in an uphill direction.

This example shows how water infrastructure is not just strategic from the engineering perspective, since it illustrate how, because of the institutional environment, engineers were forced to modify the infrastructure in a much-improvised manner, which result in a design that is not optimal. However, the point I want to make here is about the unforeseen outcomes that this modification brought in the way infrastructure perform, and the further modifications engineers need to make in the infrastructure if they want to correct these problems. The decision to cancel the mentioned pipe not only determined that water take a much longer route before reaching Bairro Central, but, also increased the time needed to supply water to this neighbourhood with two hours. To make the situation worse, in contexts of protracted interruptions in the supply service, the slope in the terrain prolongs the situation of water shortage. This happens because, by gravity, water in these pipes tends to retry and flow back to the south (see Figure 44 in Chapter 5). Eventually, the pipes in this part of the distribution network get regularly empty and when the system is restarted and water flows again, the residents have to wait on average one full day more than other neighbourhoods to have water flowing in their water taps again. The fact that they observe how other neighbourhoods have water except them increase their dissatisfaction with the utility company and make them aware of the social inequity they face in terms of water provision.

The temporal solution currently in use by the utility company to overcome the challenge to provide water to Bairro Central consists of a change in the water distribution schedule and the operation of several valves to force water to flow towards this neighbourhood. As a more permanent solution, the general manager of the company has foreseen the installation of one pipe that will connect the neighbourhoods of Matadouro and Central, using gravity to make water flow down-hill (see Figure 45 in Chapter 5). However, the measure is not implemented yet because currently it is not the priority of the utility company to make this investment.

The unpredicted performance of the water infrastructure in Bairro Central led the water utility to implement other modifications. For instance, to deal with the fugitive nature of water that escapes from the neighbourhood by gravity, the general manager arranged the installation of a non-return valve at the beginning of the pipe that conveys water to this area. When residents of Bairro Central started to complain about false lectures in their water meters, the utility company staff determined that the problem was generated by air in the pipes going out through the taps as result of this non-return valve. To solve this, the water utility has started to install "air-valves" in the area to extract this air preventing it passing through the water meters. However, one operator explained that the valves installed has been not enough to solve the problem and he suspects that it is not only about the number of valves but also their location. He has a hypothesis about where these valves could function better, but he will not have certain until seeing the valves functioning. The unforeseen functioning of the system also happens through the more fixed[58] components of the water infrastructure. For instance, the design of intake structure at the river has not foreseen the periodic drops in the water table in the river. As consequence, from time to time the water utility has to rent heavy machinery to build a small earthen weir in the river that helps to increase the water level at the intake point (see Section 4.8 for more detailed explanation). These experimental processes of trial and error and constant tinkering with the system to make it function shows the emerging nature of water infrastructure which makes it never fully complete.

As I already have shown, even when water infrastructure plays an important role in reproducing the structural asymmetries that characterize the power hierarchies in society, there is always space for contestation. This means that water infrastructure will never be totally controlled by any specific group of interests. However, there is also another reason for this: the case study of Moamba shows that the roles of the actors that interact with the water infrastructure, roles that often are considered as clearly defined and separated, are in practice blurred. Water users are often not supposed to modify the infrastructure and yet they do, becoming *de facto* a kind of engineers. Chapter 6 shows how in Moamba, water users are not only intervening the infrastructure on their own initiative but to some degree, they are expected to do so by the water utility company. The extensions made on the water distribution network by the water users are good examples of this. Considerable portions of Bairro Central were not included in the design of the network, nor during the construction, and no extension was foreseen by the utility company to change this situation neither. Nobody could foresee that a collective of Bairro Central residents would decide to recycle old pipes to extend the network, unearthing them from its original location and installing it in their neighbourhoods to make water flow towards their houses.

On the other hand, engineers are often portrayed as non-political actors who make rational decisions based on optimal designs. However, this research shows how they cannot escape from the power dynamics in which they are involved when designing, building and modifying the infrastructure. The changes in the trace of the pipelines in Bairro Central show examples of this. Particularly the changes made in order to avoid installing a pipe that crosses the railway at the point next to the train station give us a glance on the influence of the railway company to impose its will and have its interests materialized in the resulting water infrastructure.. Despite that the construction company Conduril had technical reasons to support the installation of the pipe

[58] In opposition to the valves and others pieces that can be removed and installed easily.

under the railway, and despite that this would determine a much better water supply service for Bairro Central residents, the interests of railway company prevailed. At the same time, given that the construction project did not have a budget to indemnify families that would be forced to move their houses in order to allow the installation of the pipes, the construction company had very little room for manoeuvre. As consequence, when the construction process started, the engineers and construction workers also had to deal with the interests of particular families and neighbourhoods, which resulted in the modification of the trace of the pipes in some sections of the network.

Based on the above, I could argue that water infrastructure exceeds politics, because despite what the political plans and goals are, in the end water infrastructure always acts and performs in unexpected ways, distorting these plans. The closure of the standpipes by the private utility company described in Chapter 4 is interesting in this sense. The original project to rehabilitate and extend Moamba's distribution network contemplates the increment in the number of public standpipes from 10 to 29. It caught my attention that, less than two years after the inauguration of these new water infrastructures after many years of planning and design and considerable investments, the utility company decided to close down all these standpipes, . I received three different narratives to justify this decision (see Chapter 4), however, I would like to highlight here one. This is that standpipes become an unintended source of power for particular actors, the standpipes money collectors, making the utility company unable to exert a total control over the profits produced from the water sells in these points. The general manager of the water utility said that the difficulty in controlling the income produced in each standpipe was that the money collectors did not even need to manipulate or modify the standpipes' water meters in order to steal money because the readings of these gauges were not accurate[59]. In this way, standpipes acted similarly to what Meehan (2014) refers to as "tool-power". Through the appropriation of these standpipes, the money collectors had access to a wellspring of power that allowed them to circumvent the control that the water utility company exercises not only over the water infrastructure itself but also over the benefits that it generates.

Before moving to answering what water infrastructure does, it is pertinent to briefly summarize the findings highlighted so far and its contribution to a better understanding of water infrastructure. I started mentioning that water infrastructure is, at least partially, controlled by political and engineering objectives. I also showed how this control is manifested in the role played by infrastructure in reproducing the uneven distribution of power in society and the social inequalities associated with it. However, the main contribution of my research consists in showing how the pragmatic, contingent and experimental nature of water infrastructure, in combination with the fact that there is a myriad of actors involved in the making of infrastructure, determine that water infrastructure will never be totally controlled. Our limitation to predict the outcomes water infrastructure and its emergent nature in space-time is not only the result of human action. There are a lot of variables in daily life that no actor can ever fully control and the physical environment in which water infrastructure is constructed is never fully known, producing a constant change in the physical and institutional environment and forces actors to be pragmatic and constantly tinker with the infrastructure in order to make it function. As result of these constant changes, and despite the structural asymmetries in power relations, there will always exist spaces of contestation that even the less powerful actors can

[59] Interview with Pedro Cardoso on 31.01.2018.

use to challenge and reconfigure the power dynamics in which they are immersed. This implies that water infrastructure is a wellspring of power and thus also plays an important role in processes of societal change.

To answer what infrastructure does, I will start pointing out that everybody accesses water one way or another, and there is always some sort of infrastructure involved in the process, whether they are sophisticated electronic instruments for instance at an intake station or a simple bucket. The evidence I have presented in this thesis shows that, in any case, the type of water infrastructure that mediates access to water determines to a great extent the quantity of the water that can be used; the frequency and timing of the access to water; the order in which people access water; and the quality of the water people receive[60]. And all these aspects have consequences in terms of shaping society, because it differentiates people by affecting their living conditions and producing specific forms of social relations.

For instance, in Chapter 7 I explain how water infrastructure make an important difference for the water security of families and individuals in Moamba since it is a major factor in determining the amount of water they can access and store, and in consequence, the amount of water they can consume per day. As such, water infrastructure becomes a way through which social differentiation materializes. For example, having no water-tap is by itself a sign of poor economic situation or an indicator of being a person without "planning capacity", "not responsible", "without interest in progress". If the person has no tanks to storage water neither, he or she has to reduce their water consumption to the minimum indispensable, which means that will not be able to wash the clothes with the frequency the rest people do. Wearing dirty clothes is for residents of Moamba a clear indicator of low status and has negative repercussions to socialize with other people.

This thesis also provides evidence to defend the hypothesis that water infrastructure does not solely mirror the structural asymmetries of power relations, but also can shape these relations. Quarteirão 11 is one of the blocks of houses inside Bairro Central where the residents decided to recycle old pipes to extend the water distribution network. Despite these residents achieve their goal of making water flow towards their houses, the pipe brought changes foreseen by none of them. From the beginning, the installation process of the pipe alters the social dynamics of this area, by dividing residents among those "willing" to participate in the works and/or contribute with money to afford the additional materials needed, and those who do not. Of course, this generates enmities, but what is important to highlight is that those who worked decided that those who did not have not right to connect themselves to the pipe, unless they would pay for it. Characteristics of the pipe as layout and length were defined by the need of reach the houses of people that contributed to the installation process. These characteristics made it easier for those who are close to the pipe to install private connections.

This pipe also has become a strong bond between the residents connected to it. Since they depend on the pipe, they are tied to its fate. The degree of dependence is not the same, for example, those who have a tank to store water can wait longer before being forced to find ways

[60] My research has not focused on collecting data related to water quality, but the research of my colleague Michael Quaye do. He conducted his fieldwork in Moamba at the same time than me, and his findings provides evidence that suggests water infrastructure as one of the main factors to explain the pronounced difference in the water quality of the neighbourhoods in Moamba (see for more details Quaye, 2018).

to fix a breakdown, but in general terms, every time a breakdown occurs in the pipeline all of its beneficiaries are expected to perform a minimum of involvement to fix it. These acts of "performance" are particularly interesting. During the repairing of the pipes most residents are interested in being seen working, in showing that they made their efforts in fixing the pipe, which constitute a periodic investment of labour in order to renew their property over the secondary pipe. This behaviour resembles a situation commonly present around irrigation channels in rural areas, where the hydraulic property is created based on collective action (Silva-Novoa, 2014; Isbell, 2005; Rivera Andía, 2002; Trawick, 2002), but not often documented in contexts of drinking water supply infrastructure.

This turns my gaze back to Anand's research in the city of Mumbai (2011), where he states that hydraulic citizenship is something precarious that demand constant reconfirmation. In this case, the reconfirmation has to be obtained from the rest of the water users that collectively own the pipe. Each household needs to reaquire the recognition of the rest of their neighbours that they have made themselves worthy to continue using the pipe. And at the same time, the reconfirmation of this hydraulic right also has to be obtained from the utility company, which can cut the water flow towards the secondary pipe any time if the water users do not show that they will prevent water to be wasted from leaking pipes.

On the other hand, the fact that the technicians from the utility company demanded, on behalf of the company, an investment in labour and materials from the water users raises questions about the responsibility of the company and the water users in giving maintenance to the pipe. From my perspective, the difficulty to promote a timely and adequate maintenance to the pipe, as well as to define who has to assume this maintenance, lies partially in the nature of the property itself that this pipe embodies. Since the owners can prevent others from using this conduit ("only those who worked in its installation and those that had paid to be connected can use it"), it seems to be considered as a collective property regime. But precisely because the pipe is collectively owned, it is not easy for its users to deal with the risk of free-riders. In consequence, while everybody demands to equally receive a good water supply from it, when it is needed to fix the pipe nobody wants to be the first engaging in this task because of the personal investment of resources that it demands (e.g. time, materials, labour). On the other hand, the utility company does not take the initiative either, despite it is charging monthly water bills to the individual households for service provision. The utility company can argue that they cannot intervene on the secondary pipe without the consent of the water users because this is not their property. However, by leaving all the responsibility of the pipe in hands of the users the company also conveniently reduces its maintenance cost without lowering the tariffs for water. This raises questions about the customer-supplier relationships between the water users and the water utility. At the same time the deterioration of these kinds of pipes constitute a major sour of water pollution (see also Quaya, 2018) that not only can affect the water users directly connected to it but, by as effect of the backflows, also those customer connected to other branches of the network. Since the state of the pipe is an important factor in terms of meeting water quality standards, developing a better understanding of the property regime of these pipes installed by the neighbours is very important in order to develop adequate institutional frameworks that facilitate adequate maintenance.

Depending on which pipe the users are connected to (the primary pipe installed by the company or the recycled one) and how close they are from the pipe, water infrastructure can also

differentiate users. Those who are connected to the primary pipe are less vulnerable to suffer from water shortage as result of breakdowns of the pipe. But these pipes can also differentiate users spatially, determining who receive water first and who has to wait longer for it when the water flows again after a cut in the service. Water storage infrastructure, such as cement tanks, also can differentiate people, but in this case by distinguishing particular houses among the rest by turning them into places from where people can buy water during prolonged interruptions in the water distribution service. In other words: in contexts of water shortage, the infrastructure differentiates people among those who have water and those who have not. This has the effect of strengthening solidarity bonds among Quarteirão 11 residents because those who temporally has no access to water ask for it to those who have it. In this process, an asymmetry is established in the relationship because, even if there is a payment of money involved, it is perceived that those who give water are doing something for those who receive water. The people who receive water will look for ways to return the favour and thus settle the "debt", taking the relationship beyond the mere transaction of selling-buying water.

This capability to connect people manifest in other ways. A simple water-tap can create a mutual dependency bond between two families living next to each other, one being the owner of the tap and the other contributing with the half of the money to pay the water bill. This turned out to be the base for a strong relationship since this dependency prevents protracted conflicts between the members of the households. Another type of arrangement between neighbours is establishing a flat tariff to be paid by the family without water tap. During the fieldwork in Quarteirão 11, I identified six households without water tap. The pattern seems to be that only single-parents with children are those that do not have a water-tap. Their economic situation is more precarious than the households with more than one member contributing financially to the household, and they cannot afford the installation of a private in-house water connection. In terms of water security, the vulnerability of households without water taps is related not only to the availability of a stable source of income, which can put a limit in the amount of water they can buy, but also to the composition of the household, the age of the members and their gender. These factors are directly related to the availability of labour force to carry out tasks such as fetching water for the family. Fetching water in Moamba, as well as domestic water use practices in general, is a female activity. If the households are composed of only one adult and small children, the availability of labour source to fetch water and produce income for the household will be severely reduced. In consequence, these type of household develops a greater degree of dependence on their neighbours.

The proliferation of private connections also isolate families that used to have strong relationships before the extension of the distribution network into the neighbourhood. This has gone hand in hand with the fact that, since women do not need to spend long hours waiting for their turn to buy water from a public standpipe and spend more time at home, the number of conflicts between neighbours has, according to interviewees, increased along with gossips[61]. This seems to contradict my previous statement about water infrastructure promoting relationships of solidarity and reciprocity. But this can be interpreted in another way: by creating free time for the residents of any specific neighbourhood, in-house water connections increase and intensify social activity in this space. In consequence, both outcomes are possible

[61] Interview with IN27, IN29 and their daughters.

at the same time: the increase of conflicts as the development of solidarity and reciprocity bonds. This is a hypothesis that needs further investigation in order to be confirmed.

In terms of everyday practices, the presence of a private connection has had a huge impact on women's lives and in their relationships with husbands and children. Before the water network was installed in Bairro Central, women needed to spend long hours at standpipes waiting for their turn to buy water, and not always received enough. After repeated trips from the house to the standpipe and from here to the house to transport water, women had to keep working in household chores, so they did not have time (nor energy) to do anything else. The relationship between spouses does not necessarily improve with a water-tap but in general terms, the couple has more time to spend together. The interviewees said that this freed time could be used by the couple to go together to the farm or in recreational activities, as well as dedicate more time to raise their children, to talk to them, to teach them and help them with their homework. Children do not need to skip hours from school to help their mothers to load the water drums from the standpipe to the house, which has alleviated mothers' feelings of guilt. Women also use this freed time to rest and chatting with friends. I found, as Van Houweling (2016) did in her research about gender roles and water practices in the northern Mozambican region of Nampula, that improving women's access to water infrastructure do not lead necessarily to a change in gender roles, but improve their living conditions and those of children[62].

I would like to finish with a short reflection on the theoretical framework used within this research. What new could it bring to talk about infrastructure in terms of exercising agency? What could it bring to the understanding of everyday water practices and the role of water infrastructure in processes of social change? The concept of material agency perhaps is not the best to explore the implications of a sociotechnical ontology of water infrastructure since it leads to the comparison with human agency, characterized by being goal-oriented and, to a great extent, conscious. However, it does allows us to approach the emergent nature of water infrastructure and its active role in shaping processes of change. By approaching objects as active participants in the course of actions that alter the estate of affairs of the world (Latour; 2005), this concept forces us to take our way of thinking about water infrastructure beyond the traditional conceptualization of infrastructure merely as a tool that produces an effect. The adoption of this less deterministic approach to study water infrastructure allowed me to find how water infrastructure escapes, at least partially, human control. Whether it assumes the form of the carefully planned interventions aligned with particular objectives, whether from politicians and engineers, or the more experimental tinkering of construction workers, operators and water users, the outcomes produced by its functioning are in a great extent unpredictable. In this sense, considering water infrastructure merely as a tool capable of an effect is not recognizing its inherent contingent and elusive nature, neither its capability to constantly reconfigure socio-nature relations.

This research could also be critiqued on the use of perhaps not so well defined concepts such as "pragmatic", "experimental", and "contingent". The way I interchange "pragmatic" with expressions such as "in an improvised way" and "ad-hoc"; or "experimental" with "trial and error"; and "contingent" with "emergent in space and time" could be interpreted as lack of

[62] In general terms my findings around the impact that having a water private connection has on women's lives in Moamba are aligned to the findings found by Van Houweling (2016).

clarity or consistency. However, this is rather symptomatic of the search for a suitable terminology that expresses the complexity implied in studying water infrastructure beyond its mere materiality. I admit, concepts are more than just semantics yet at the same time, as state in the introduction of this thesis, the set-up of this research is explorative and as such this research, and the concepts I draw on, is also to some extent emerging in time and space.

References

Adank, M. and Tuffuor, B., 2013. Management models for the provision of small town and periurban water services in Ghana. Accra: TPP Project/RCN Ghana.

Ahlers, Rhodante; Perez Güida, Valeria; Rusca, María and Schwartz, Klaas (2013). Unleashing Entrepreneurs or Controlling Unruly Providers? The Formalisation of Small-scale Water Providers in Greater Maputo, Mozambique. Journal of Development Studies, Vol. 49, No. 4, p. 470–482, April 2013.

Allan, T. (2003). IWRM/IWRAM: a new sanctioned discourse? Occasional Paper 50. SOAS Water Issues Study Group. School of Oriental and Afriacan Studies, King's College, London.

Anand, N. (2011). Pressure: The politechnics of water supply in Mumbai. Cultural Anthropology 26 (4): p. 542 - 564.

Ashcraft, C. M., & Mayer, T. (2016). The Politics of Fresh Water: Access, conflict and identity: Routledge

Babbie, E. and Moutgon, J. (1998). The Practice of Social Research, South African Edition. Cape Town, Oxford University Press Southern Africa Limited.

Bakker, K., 2012. Water: political, biopolitical, material. Social Studies of Science 42 (4), 616–623.

Boelens, R., & Vos, J. (2012). The danger of naturalizing water policy concepts: Water productivity and efficiency discourses from field irrigation to virtual water trade. Agricultural Water Management, 108, 16-26.

Brown, H. I. (1988). Rationality. London, Routledge.

Burawoy, M. (1991). The extended case study method. In Burawoy M. ,Burton, A., Ferguson, A. A., Fox, K., Ganson, J., Gartrell, N., Hurst, L., Kurzman C., Salzinger, L., Schiffman, J., Ui, S. (eds.) Ethnography unbond: power and resistance in the modern metropolis. Berkely, University of California Press: 271 - 290.

Burger, Christian (2014). Pathways to practice: praxiography and international politics. European Political Science Review (2014), 6: 3, 383 - 406.

Cleaver, Frances and De Koning, Jessica (2015). Furthering critical institutionalism. International Journal of the Commons. Vol. 9. no 1 March 2015. p. 1 - 18.

Collignon, Bernard; Vezina, Marc. 2001. Independent water and sanitation providers in African cities - full report of a ten-country study. Water and sanitation program. Washington, D.C.: World Bank Group.

Cook, C., & Bakker, K. (2012). Water security: Debating an emerging paradigm. Global Environmental Change, 22(1), 94-102

Coutard O (1994) Economics of grid systems in reconfiguration: Competition in the electricity supply industry. In: Summerton J (ed.) Changing Large Technical Systems. Boulder, CO: Westview Press, 163–189

David J. and Pilgrim N., 2000. Annotated Bibliography for the Small Towns Water and Sanitation Electronic Conference. S.l.: WSP: Water and Sanitation Program of the World Bank and Loughborough: WEDC-Water, Engineering and Development Centre.

Emily Van Houweling (2016) “A Good Wife Brings Her Husband Bath Water”: Gender Roles and Water Practices in Nampula, Mozambique, Society & Natural Resources, 29:9, 1065-1078.

Furlong, K. (2010). Small technologies, big change: rethinking infrastructure through STS and geography. Progress in Human Geography 35 (4): p. 460 - 482.

Gandy M (2005) Cyborg urbanization: Complexity and monstrosity in the contemporary city. International Journal of Urban and Regional Research 29: 26–49.

Geertz, Clifford (1973). The Interpretation of Cultures. Basic Books, Inc., Nueva York, 1973, p. 470

Grey, D., & Sadoff, C. W. (2007). Sink or swim? Water security for growth and development. Water Policy, 9(6), 545-571.

Grumbine, R. E., & Xu, J. (2011). Mekong hydropower development. Science, 332(6026), 178-179.

Heynen N, Kaïka M, and Swyngedouw E. (eds) (2006). In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Abingdon: Routledge.

Hughes, T. 1989. American Genesis: A Century of Innovation and Technological Enthusiasm, 1870-1970. New York: Penguin.

Hughes, T. 1990. From deterministic dynamos to seamless-web systems. In Engineering as a Social Enterprise, ed. H. Sladovich, pp. 7-25. Washington: Natl. Acad. Press.

Isbell, Billie Jean, (2005). Para defendernos: Ecología y ritual en un pueblo andino. Cusco: Centro de Estudios Regionales Andinos Bartolomé de Las Casas, p. 335.

Jensen, C. B. (2016). Pipe Dreams: Sewage Infrastructure and Activity Trails in Phnom Penh. Ethnos, 1-21.

Jensen, C. B., and Morita, et al. (2016). Infrastructures as Ontological Experiments. Ethnos, 1 - 12.

Kemerink-Seyoum, J. S. (2015). Policies lost in translation? Unravelling water reform processes in African waterscapes: UNESCO-IHE, Institute for Water Education.

Koech, R., Smith, R., & Gillies, M. (2014). A real-time optimisation system for automation of furrow irrigation. Irrigation Science, 32(4), 319-327.

Kooy, Michelle and Bakker, Karen (2008). Splintered networks: The colonial and contemporary waters of Jakarta. Geoforum 39 (2008) 1843 - 1858.

Larkig, Brian (2013). The politics and poetics of infrastructure. Annual Reviwe of Anthropology, 42: 327 - 343.

Latour, B. 1993. We Have Never Been Modern. London: Harvester Wheatsheaf

Le, T. V. H., Nguyen, H. N., Wolanski, E., Tran, T. C., & Haruyama, S. (2007). The combined impact on the flooding in Vietnam's Mekong River delta of local man-made structures, sea level rise, and dams upstream in the river catchment. Estuarine, Coastal and Shelf Science, 71(1), 110-116.

Limb, M. and Dwyer, C. (eds.) (2001). Qualitative methodologies for geographers: Issues and debates. London, Arnold.

Masseroni, D., Ricart, S., de Cartagena, F. R., Monserrat, J., Gonçalves, J. M., de Lima, I., Gandolfi, C. (2017). Prospects for Improving Gravity-Fed Surface Irrigation Systems in Mediterranean European Contexts. Water, 9(1), 20.

McFarlane C and Rutherford J (2008) Political infrastructures: Governing and experiencing the fabric of the city. International Journal of Urban and Regional Research 32: 363–374.

Meehan, K., M. (2014). Tool-power: Water infrastructure as wellsprings of state power. Geoforum; p. 10.

Molle, F., Mollinga, P. P., & Wester, P. (2009). Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. Water Alternatives, 2(3), 328-349.

Moss, T. (2014). Socio-technical change and the politics of urban infrastructure: Managing Energy in Berlin between Dictatorship and Democracy. Urban Studies 51 (7) 1432 - 1448, May 2014.

MOZAMBIQUE, INE (2010). Projecções Anuais da População Total, Urbana e Rural, dos Distritos da Província de Maputo 2007 – 2040. Rescued on 02.03.2018 from http://www.ine.gov.mz/estatisticas/estatisticas-demograficas-e-indicadores-sociais/projeccoes-da-populacao/populacao-projectada-por-distritos-maputo-provincia-2007_2040.xls/view.

Obertreis, J.; Moss, t.; Mollinga, P. and Bichsel, C. (2016). Water, infrastructure and political rule: Introduction to the Special Issue. Water Alternatives 9 (2): 168 - 181.

Ortner, S.B. (1984). Theory in anthropology since the sixties. Comparative Studies in Society and History 26(1): 126 - 166.

Pfaffenberger, Bryan (1992). Social Anthropology of Technology. Annual Review of Anthropology. Vol. 212 (1992), pp. 491 - 516. Annual Reviews

Pickering, A. (1993). The Mangle of Practice: Agency and Emergence in the Sociology of Science. American Journal of Sociology, Vol. 99, No. 3 (Nov., 1993), pp. 559-589.

Pilgrim, N., Roche, B., Kalbermatten, J., Revels, C., and Kariuki, M., 2007. *Principles of town water supply and sanitation, Part 1: water supply*. Water Working Note 13. Washington DC: The World Bank.

Plano de Segurança da Água – Sistema secundário da Vila da Moamba. Módulo 2 - Descrição do sistema de abastecimento de água da Moamba, p. 09.

Pulido, Laura (2016). Flint, Environmental Racism, and Racial Capitalism, Capitalism Nature Socialism, 27: 3, pp. 1 - 16.

Reevs, Madeline (2016). Infrastructural hope: anticipating independent roads and territorial integrity in Southern Kyrgyzstan. Ethnos 82: 4, pp. 711 - 737.

Rivera Andía, Juan Javier (2002). Ritos agrícolas en el valle del Chancay (Lima). Testimonios sobre las celebraciones en torno a la limpieza de acequias recopilados cuarenta años después. En: Anthropológica, vol. 20, noº 20, Lima: 2002.

Rodina, L. and Harris, M. H. (2016). Water Services, Lived Citizenship, and Notions of the State in Marginalised Urban Spaces: The case of Khayelitsha, South Africa. Water Alternatives 9 (2): pp. 336 - 355.

Sahlins, Marshall. (1972). Stone Age Economics.Chicago: Aldine.

Schwartz, K., Tutusaus Luque, M., Rusca, M., and Ahlers, R. (2015). (In)formality: the meshwork of water service provisioning. WIREs Water 2015, 2:31–36. doi: 10.1002/wat2.1056.

Silva-Novoa Sánchez, L. (2014). La fiesta de la Champeria en San Pedro de Casta como espacio de legitimación de la sociotecnología andina. Patrimonio, Identidad y Memoria. Sandra Negro and Samuel Amoros (eds.) Instituto de Investigación del Patrimonio Cultura, Universidad Ricardo Palma. Editorial Universitario 2014. Lima, Perú, pp. 339 - 356.

Spradley, J. (1979). The ethnographic interview. Fort Worth: Harcourt Brace Jovanovich College Publishers.

Sultana, F. Suffering for water, suffering from water: Emotional geographies of resource access, control and conflict. Geoforum 42 (2011) 163 - 172.

Swyngedouw E (2009) Circulations and metabolisms: (Hybrid) natures and (cyborg) cities. In: White DF and Wilbert C (eds) Technonatures: Environments, Technologies, Spaces, and Places in the Twenty-first Century. Waterloo, ON: Wilfred Laurier University Press, 61–84.

Swyngedouw E. (2006). Metabolic urbanization The making of cyborg cities. Heynen N, Kaïka M, and Swyngedouw E. (eds) (2006). In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Abingdon: Routledge.

Swyngedouw, E. (1997). Power, nature, and the city. The conquest of water and the political ecology of urbanization in Guayaquil. Environment and Planning A 1997, volume 29, pp. 311 - 332.

Swyngedouw, E. (1999). Modernity and hybridity: Nature, regeneracionismo, and the production of the Spanish waterscape, 189+0 - 1930. Annals of the Association of American Geographers 89: p. 443 - 465.

Tavengwa, C. (2017). Understanding agency of water infrastructure in everyday agricultural water politics: A case of the Manjirenji covenyance canal, Zimbabwe. MSc thesis UNESCO-IHE, The Netherlands.

Trawick, Paul, (2002) Comedy and tragedy in the Andean Commons. En: Journal of Political Ecology, vol. 9, p.34

Truelove, Y. (2011). (Re-) Conceptualizing water inequality in Delhi, India through a feminist political ecology framework.

UN-HABITAT-United Nations Human Settlements Program, 2006. Meeting development goals in small urban centres: Water and sanitation in the world's cities. [pdf] London: Earthscan. Available at: <http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2057> [Accessed 14 September 2017].

Universidade Eduardo Mondlane - Project Water supply and sanitation in small towns (2017). Relatório De Água E Saneamento (Versão Final-Volume I): p.61.

White DF and Wilbert C (2009a) Introduction: Inhabiting technonatural time/spaces. In: White DF and Wilbert C (eds) Technonatures: Environments, Technologies, Spaces, and Places in the Twenty-first Century. Waterloo, ON: Wilfred Laurier University Press, 1–30.

Wutich, Amber (2009). Intrahousehold disparities in women and men's experiences of water insecurity and emotional distress in urban Bolivia. Medical Anthropoligy Quarterly, Vol. 23, Issue 4, pp. 436-454.

Yin, R. K. (2003). Case study research: Design and methods. Third edition. London, Sage Publication.

Zwarteveen, Margreet Z. and Boelens, Rutgerd (2014). Defining, researching and struggling for water justice: some conceptual building blocks for research and action. Water International, 2014. Vol. 39, No.2, 143 - 158.

Adank, M. and Tuffuor, B., 2013. Management models for the provision of small town and periurban water services in Ghana. Accra: TPP Project/RCN Ghana.

Ahlers, Rhodante; Perez Güida, Valeria; Rusca, María and Schwartz, Klaas (2013). Unleashing Entrepreneurs or Controlling Unruly Providers? The Formalisation of Small-scale Water Providers in Greater Maputo, Mozambique. Journal of Development Studies, Vol. 49, No. 4, p. 470–482, April 2013.

Allan, T. (2003). IWRM/IWRAM: a new sanctioned discourse? Occasional Paper 50. SOAS Water Issues Study Group. School of Oriental and Afriacan Studies, King's College, London.

Anand, N. (2011). Pressure: The politechnics of water supply in Mumbai. Cultural Anthropology 26 (4): p. 542 - 564.

Ashcraft, C. M., & Mayer, T. (2016). The Politics of Fresh Water: Access, conflict and identity: Routledge

Babbie, E. and Moutgon, J. (1998). The Practice of Social Research, South African Edition. Cape Town, Oxford University Press Southern Africa Limited.

Bakker, K., 2012. Water: political, biopolitical, material. Social Studies of Science 42 (4), 616–623.

Boelens, R., & Vos, J. (2012). The danger of naturalizing water policy concepts: Water productivity and efficiency discourses from field irrigation to virtual water trade. Agricultural Water Management, 108, 16-26.

Brown, H. I. (1988). Rationality. London, Routledge.

Burawoy, M. (1991). The extended case study method. In Burawoy M. ,Burton, A., Ferguson, A. A., Fox, K., Ganson, J., Gartrell, N., Hurst, L., Kurzman C., Salzinger, L., Schiffman, J., Ui, S. (eds.) Ethnography unbond: power and resistance in the modern metropolis. Berkely, University of California Press: 271 - 290.

Burger, Christian (2014). Pathways to practice: praxiography and international politics. European Political Science Review (2014), 6: 3, 383 - 406.

Cleaver, Frances and De Koning, Jessica (2015). Furthering critical institutionalism. International Journal of the Commons. Vol. 9. no 1 March 2015. p. 1 - 18.

Collignon, Bernard; Vezina, Marc. 2001. Independent water and sanitation providers in African cities - full report of a ten-country study. Water and sanitation program. Washington, D.C.: World Bank Group.

Cook, C., & Bakker, K. (2012). Water security: Debating an emerging paradigm. Global Environmental Change, 22(1), 94-102

Coutard O (1994) Economics of grid systems in reconfiguration: Competition in the electricity supply industry. In: Summerton J (ed.) Changing Large Technical Systems. Boulder, CO: Westview Press, 163–189

David J. and Pilgrim N., 2000. Annotated Bibliography for the Small Towns Water and Sanitation Electronic Conference. S.l.: WSP: Water and Sanitation Program of the World Bank and Loughborough: WEDC-Water, Engineering and Development Centre.

Emily Van Houweling (2016) “A Good Wife Brings Her Husband Bath Water”: Gender Roles and Water Practices in Nampula, Mozambique, Society & Natural Resources, 29:9, 1065-1078.

Furlong, K. (2010). Small technologies, big change: rethinking infrastructure through STS and geography. Progress in Human Geography 35 (4): p. 460 - 482.

Gandy M (2005) Cyborg urbanization: Complexity and monstrosity in the contemporary city. International Journal of Urban and Regional Research 29: 26–49.

Geertz, Clifford (1973). The Interpretation of Cultures. Basic Books, Inc., Nueva York, 1973, p. 470.

Grey, D., & Sadoff, C. W. (2007). Sink or swim? Water security for growth and development. Water Policy, 9(6), 545-571.

Grumbine, R. E., & Xu, J. (2011). Mekong hydropower development. Science, 332(6026), 178-179.

Heynen N, Kaïka M, and Swyngedouw E. (eds) (2006). In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Abingdon: Routledge.

Hughes, T. 1989. American Genesis: A Century of Innovation and Technological Enthusiasm, 1870-1970. New York: Penguin.

Hughes, T. 1990. From deterministic dynamos to seamless-web systems. In Engineering as a Social Enterprise, ed. H. Sladovich, pp. 7-25. Washington: Natl. Acad. Press.

Isbell, Billie Jean, (2005). Para defendernos: Ecología y ritual en un pueblo andino. Cusco: Centro de Estudios Regionales Andinos Bartolomé de Las Casas, p. 335.

Jensen, C. B. (2016). Pipe Dreams: Sewage Infrastructure and Activity Trails in Phnom Penh. Ethnos, 1-21.

Jensen, C. B., and Morita, et al. (2016). Infrastructures as Ontological Experiments. Ethnos, 1 - 12.

Kemerink-Seyoum, J. S. (2015). Policies lost in translation? Unravelling water reform processes in African waterscapes: UNESCO-IHE, Institute for Water Education.

Koech, R., Smith, R., & Gillies, M. (2014). A real-time optimisation system for automation of furrow irrigation. Irrigation Science, 32(4), 319-327.

Kooy, Michelle and Bakker, Karen (2008). Splintered networks: The colonial and contemporary waters of Jakarta. Geoforum 39 (2008) 1843 - 1858.

Larkig, Brian (2013). The politics and poetics of infrastructure. Annual Reviwe of Anthropology, 42: 327 - 343.

Latour, B. 1993. We Have Never Been Modern. London: Harvester Wheatsheaf

Le, T. V. H., Nguyen, H. N., Wolanski, E., Tran, T. C., & Haruyama, S. (2007). The combined impact on the flooding in Vietnam's Mekong River delta of local man-made structures, sea level rise, and dams upstream in the river catchment. Estuarine, Coastal and Shelf Science, 71(1), 110-116.

Limb, M. and Dwyer, C. (eds.) (2001). Qualitative methodologies for geographers: Issues and debates. London, Arnold.

Masseroni, D., Ricart, S., de Cartagena, F. R., Monserrat, J., Gonçalves, J. M., de Lima, I., Gandolfi, C. (2017). Prospects for Improving Gravity-Fed Surface Irrigation Systems in Mediterranean European Contexts. Water, 9(1), 20.

McFarlane C and Rutherford J (2008) Political infrastructures: Governing and experiencing the fabric of the city. International Journal of Urban and Regional Research 32: 363–374.

Meehan, K., M. (2014). Tool-power: Water infrastructure as wellsprings of state power. Geoforum; p. 10.

Molle, F., Mollinga, P. P., & Wester, P. (2009). Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. Water Alternatives, 2(3), 328-349.

Moss, T. (2014). Socio-technical change and the politics of urban infrastructure: Managing Energy in Berlin between Dictatorship and Democracy. Urban Studies 51 (7) 1432 - 1448, May 2014.

MOZAMBIQUE, INE (2010). Projecções Anuais da População Total, Urbana e Rural, dos Distritos da Província de Maputo 2007 – 2040. Rescued on 02.03.2018 from http://www.ine.gov.mz/estatisticas/estatisticas-demograficas-e-indicadores-sociais/projeccoes-da-populacao/populacao-projectada-por-distritos-maputo-provincia-2007_2040.xls/view.

Obertreis, J.; Moss, t.; Mollinga, P. and Bichsel, C. (2016). Water, infrastructure and political rule: Introduction to the Special Issue. Water Alternatives 9 (2): 168 - 181.

Ortner, S.B. (1984). Theory in anthropology since the sixties. Comparative Studies in Society and History 26(1): 126 - 166.

Pfaffenberger, Bryan (1992). Social Anthropology of Technology. Annual Review of Anthropology. Vol. 212 (1992), pp. 491 - 516. Annual Reviews

Pickering, A. (1993). The Mangle of Practice: Agency and Emergence in the Sociology of Science. American Journal of Sociology, Vol. 99, No. 3 (Nov., 1993), pp. 559-589.

Pilgrim, N., Roche, B., Kalbermatten, J., Revels, C., and Kariuki, M., 2007. *Principles of town water supply and sanitation, Part 1: water supply*. Water Working Note 13. Washington DC: The World Bank.

Plano de Segurança da Água – Sistema secundário da Vila da Moamba. Módulo 2 - Descrição do sistema de abastecimento de água da Moamba, p. 09.

Pulido, Laura (2016). Flint, Environmental Racism, and Racial Capitalism, Capitalism Nature Socialism, 27: 3, pp. 1 - 16.

Reevs, Madeline (2016). Infrastructural hope: anticipating independent roads and territorial integrity in Southern Kyrgyzstan. Ethnos 82: 4, pp. 711 - 737.

Rivera Andía, Juan Javier (2002). Ritos agrícolas en el valle del Chancay (Lima). Testimonios sobre las celebraciones en torno a la limpieza de acequias recopilados cuarenta años después. En: Anthropológica, vol. 20, nº 20, Lima: 2002.

Rodina, L. and Harris, M. H. (2016). Water Services, Lived Citizenship, and Notions of the State in Marginalised Urban Spaces: The case of Khayelitsha, South Africa. Water Alternatives 9 (2): pp. 336 - 355.

Sahlins, Marshall. (1972). Stone Age Economics.Chicago: Aldine.

Schwartz, K., Tutusaus Luque, M., Rusca, M., and Ahlers, R. (2015). (In)formality: the meshwork of water service provisioning. WIREs Water 2015, 2:31–36. doi: 10.1002/wat2.1056.

Silva-Novoa Sánchez, L. (2014). La fiesta de la Champeria en San Pedro de Casta como espacio de legitimación de la sociotecnología andina. Patrimonio, Identidad y Memoria. Sandra Negro and Samuel Amoros (eds.) Instituto de Investigación del Patrimonio Cultura, Universidad Ricardo Palma. Editorial Universitario 2014. Lima, Perú, pp. 339 - 356.

Spradley, J. (1979). The ethnographic interview. Fort Worth: Harcourt Brace Jovanovich College Publishers.

Sultana, F. Suffering for water, suffering from water: Emotional geographies of resource access, control and conflict. Geoforum 42 (2011) 163 - 172.

Swyngedouw E (2009) Circulations and metabolisms: (Hybrid) natures and (cyborg) cities. In: White DF and Wilbert C (eds) Technonatures: Environments, Technologies, Spaces, and Places in the Twenty-first Century. Waterloo, ON: Wilfred Laurier University Press, 61–84.

Swyngedouw E. (2006). Metabolic urbanization The making of cyborg cities. Heynen N, Kaïka M, and Swyngedouw E. (eds) (2006). In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism. Abingdon: Routledge.

Swyngedouw, E. (1997). Power, nature, and the city. The conquest of water and the political ecology of urbanization in Guayaquil. Environment and Planning A 1997, volume 29, pp. 311 - 332.

Swyngedouw, E. (1999). Modernity and hybridity: Nature, regeneracionismo, and the production of the Spanish waterscape, 189+0 - 1930. Annals of the Association of American Geographers 89: p. 443 - 465.

Tavengwa, C. (2017). Understanding agency of water infrastructure in everyday agricultural water politics: A case of the Manjirenji covenyance canal, Zimbabwe. MSc thesis UNESCO-IHE, The Netherlands.

Trawick, Paul, (2002) Comedy and tragedy in the Andean Commons. En: Journal of Political Ecology, vol. 9, p.34

Truelove, Y. (2011). (Re-) Conceptualizing water inequality in Delhi, India through a feminist political ecology framework.

UN-HABITAT-United Nations Human Settlements Program, 2006. Meeting development goals in small urban centres: Water and sanitation in the world's cities. [pdf] London: Earthscan. Available at: <http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2057> [Accessed 14 September 2017].

Universidade Eduardo Mondlane - Project Water supply and sanitation in small towns (2017). Relatório De Água E Saneamento (Versão Final-Volume I): p.61.

White DF and Wilbert C (2009a) Introduction: Inhabiting technonatural time/spaces. In: White DF and Wilbert C (eds) Technonatures: Environments, Technologies, Spaces, and Places in the Twenty-first Century. Waterloo, ON: Wilfred Laurier University Press, 1–30.

Appendices

A. Set-up of data collection

¿How?		Source of data	Technics of data collection	Data management	Data analysis
1.1 Building a matrix to compare the infrastructure characteristics in each stage: design, construction, extension	1.1.1 Design	1.1.1.1 Design maps, feasibility reports, bill of quantities, master plans (other official documents?). 1.1.1.2 Explainations of engineers familiarized with the design and the built infrastructure.	1.1.1.1 Archive review. 1.1.1.2 Semi-structured interviewing	1.1.1.1.1 Copy of documents and archive (it is possible) 1.1.1.1.2 The data in the documents will be organized and entered in Table 3. 1.1.1.2.1 Interview narratives	Content analysis (Use of Table 3 to organize the data)
	1.1.2 Construction (built infrastructure)	1.1.2.1 Infrastructure it self 1.1.2.2 Testimony of engineers and infrastructure users to clarifications and to know of changes of which there is no trace in the current form of the infrastructure. 1.1.2.3 Satelite images.	1.1.2.1.1 Non-participant observation 1.1.2.1.2 Audio-visual methods (pictures and videos) 1.1.2.2.1 Semi-structured interviewing 1.1.2.3.1 Running of line-time satelite images (Google Earth).	1.1.2.1.1 Observation notes (included schemes). 1.1.2.1.2 Audio-visual archive and Data from audio-visual material entered in Table 3. 1.1.2.2.1 Interview narratives notes 1.1.2.3.1 Archive of time series of images.	
	1.1.3 Extension and other modifications	1.1.3.1 Testimony of those who modify the infrastructure, witnesses of the process, users engaged with the infrastructure in everyday practice, and specialist engaged in the design, construction, operation and maintenance of the infrastructure. 1.1.3.2 Process/practices of infrastructure modification in process.	1.1.3.1.1 Semi-structured interviwing 1.1.3.2.1 Non-participant observation. 1.1.3.2.2 Audio-visual methods (tentative).	1.1.3.1.1 Interview narratives notes. 1.1.3.2.1 Observation notes 1.1.3.2.2 Audio-visual archive. The data in this material organized and entered in Table 3.	

2.1 Collecting stories about how the infrastructure has change over time to identify relations between human and non-human acts and infrastructural change.	Testimony of witnesses of the infrastructure history: - infrastructure users. - people involve in the design, construction, operation and maintenance.	In-depth interviewing	Interview narratives.	2.1 Tematical analysis
2.2 Producing time-lines to identify the changes		Time-lines	Time-lines	
2.3 Producing thick descriptions of the processes/practices of infrastructure change occuring during field work to identify causal-effect relations between human and non-human acts and infrastructural change.	2.3.1 Testimony ofwitnesses of the infrastructure history: - infrastructure users. - people involve in the design, construction, operation and maintenance. 2.3.2 Process/practices of infrastructure modification in progress.	1.1.3.1.1 In-depth interviwing 1.1.3.2.1 Non-participant observation. 1.1.3.2.2 Audio-visual methods (tentative).	1.1.3.1.1.1 Interview narratives notes. 1.1.3.2.1.1 Observation notes. 1.1.3.2.2.1 Audio-visual archive. The data in this material organized and entered in Table 3.	
3.1 Producing thick descriptions of the changes in the social relations of the community of infrastructure users and in the physical environment.	Testimony of water infrastructure users. Testimony of specialists involved in the design, construction, operation and maintenance.	3.1.1 In-depth interviwing	3.1.1.1 Interview narrative notes.	
3.2 Producing time-lines to identify the changes and visualize the possible connections with processes in other scales.		3.2.1 Time-lines	3.2.1.1 Time-lines	