Systems Dynamics Modelling of the Water Supply Problem in the Limpopo Province of South Africa

Motsi Ephrey Matlakala
Department of Mechanical and Industrial Engineering Technology
University of Johannesburg
Johannesburg, South Africa
motsiephrey@gmail.com

Daramy Vandi Von Kallon
Department of Mechanical and Industrial Engineering Technology
University of Johannesburg
Johannesburg, South Africa
dkallon@uj.ac.za

Abstract

Most of poor rural communities based in the North-Eastern parts of South Africa such as in the Limpopo province face shortage of water with mostly no access to clean portable water. The water shortage is caused by the lack of proper management of the existing water systems, such that water is lost in the system through leaking and burst pipes. The water scarcity has become the top agenda priority for the local governments in the province especially considering the drought level due to lack of rain. The issue of water scarcity affects households as well as the industrial and agricultural sectors serving these rural communities. Most of the areas have contaminated water because of lack of proper purification plants and pumping systems. The purpose of this study is to model the water supply chain to determine the nature and causes of poor delivery in the system. System dynamic model is developed using the Vensim software. The system is simulated to determine opportunities for improvement. The systems dynamics modelling is discussed herein.

Keywords
Pumping System, Water, Communities, Pipes, Efficiency, System Dynamics, Simulation.

1. Introduction

South Africa is a country with a shortage of water and portable water in different areas especially rural areas. The country's population increases at a high rate but the bulk of water supply is not increasing, as a results there is shortage of water to supply the current settlements (Matlakala & Kallon, 2019). This study is focused on the rural areas in the Limpopo Province of South Africa. The Limpopo Province lies in North East of South Africa bordering Mozambique, Mpumalanga Province, Gauteng Province, North West Province, Botswana and Zimbabwe, see Figure 2. Limpopo covers 10.3%, see Figures 1 and 2. The province has a large number of the townships, urban, rural areas and surrounding industries and mines. The old mines also pollute the groundwater (Mafanya et al, 2019a; Mafanya et al, 2019b; Mafanya, 2021).

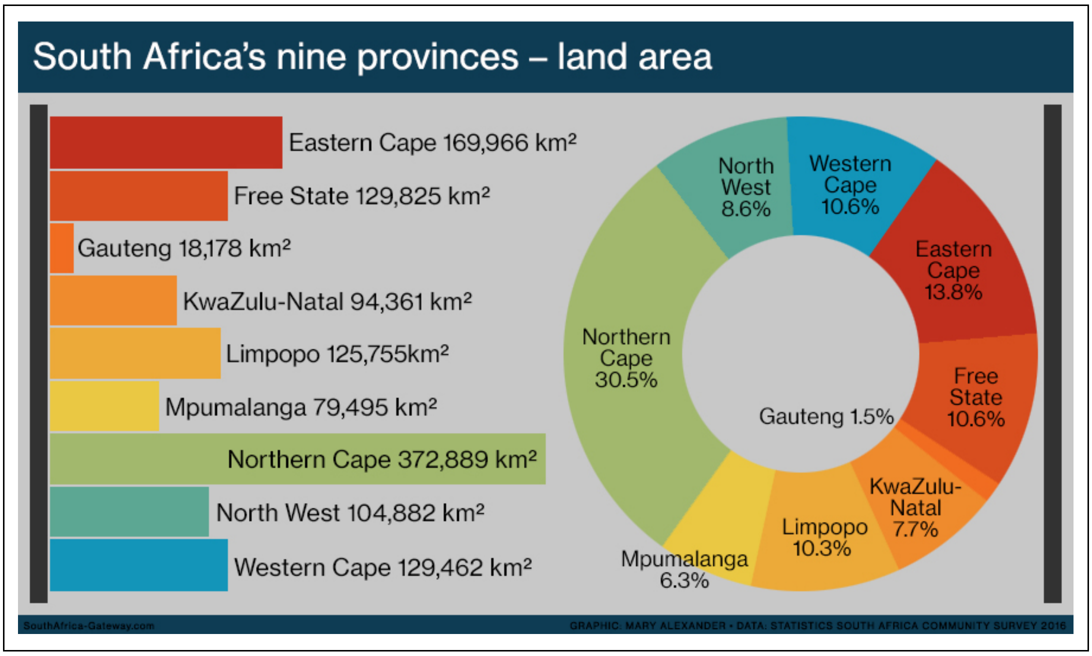

Figure 1: Land of Limpopo Province in South African Country (Alexander, 2018)

The current hot temperature in the country has plunged Limpopo Province with a water stressed as levels of dams and rivers has dropped to low percentages due to lack of rain. The infrastructures are not well maintained and managed to meet the demand of water to the communities, as a result, they don't last (Matlakala & Kallon, 2019). The low incomes communities in the province rely on the pit latrines as their primary means of sanitation. The pit latrines cause human and ecological health impacts associated with microbiological and chemical contamination of groundwater (Graham & Polizzotto, 2013).

Figure 2: The Map of South Africa with 9 Provinces (Ngaka & Zwane, 2018)

Other communities buy water from the household with boreholes and the water is not treated as a result it puts the life of the community members at higher risk. There is also unsafe construction due to illegal connections which overload the pumping system and the water supply. Provision of alternative water sources such as Atmospheric Water Generators *(AWG0 have been investigated for rural areas in South Africa, although these are not in wide use (Thisani et al, 2017; Thisani, 2018; Thisani et al, 2019). This study investigates the challenges that influence the delivery of unclean water services in Limpopo Province rural communities, specifically looking at the problems and issues that affect the delivery of services in the Province. A model of water systems and population is developed to assist with conquering the shortage of water due to increase of population, drought, and mismanagement of infrastructures which affect the water quality (Matlakala, et al., 2019; Matlakala, et al., 2019).

2. Study Areas

The study areas focus on villages in Greater Tubatse municipality. The villages are Kgopaneng, Makubu, Malokela and Ga-Phala. The villages are located at the North Western side of Greater Tubatse District Municipality and they are 52.1 km away from Burgersfort town, see Figure 3. The population and the size of the selected areas are shown in Table 1 (Anon, 2019). The study Areas depend more on boreholes and rain to get water services. There is a shortage of water and portable water because the municipality could not increase the bulk of water as the population was increasing, therefore, large several households are short of water.

Table 1: Population and Area of Kgopaneng, Makubu, Malokela and Ga-Phala

Local Municipality	**Population**	**Area km^2**
Kgopaneng	1610	2.44
Makubu	2826	4.61
Malokela	1676	1.91
Ga-Phala	1188	3.04
Total	**7300**	**12**

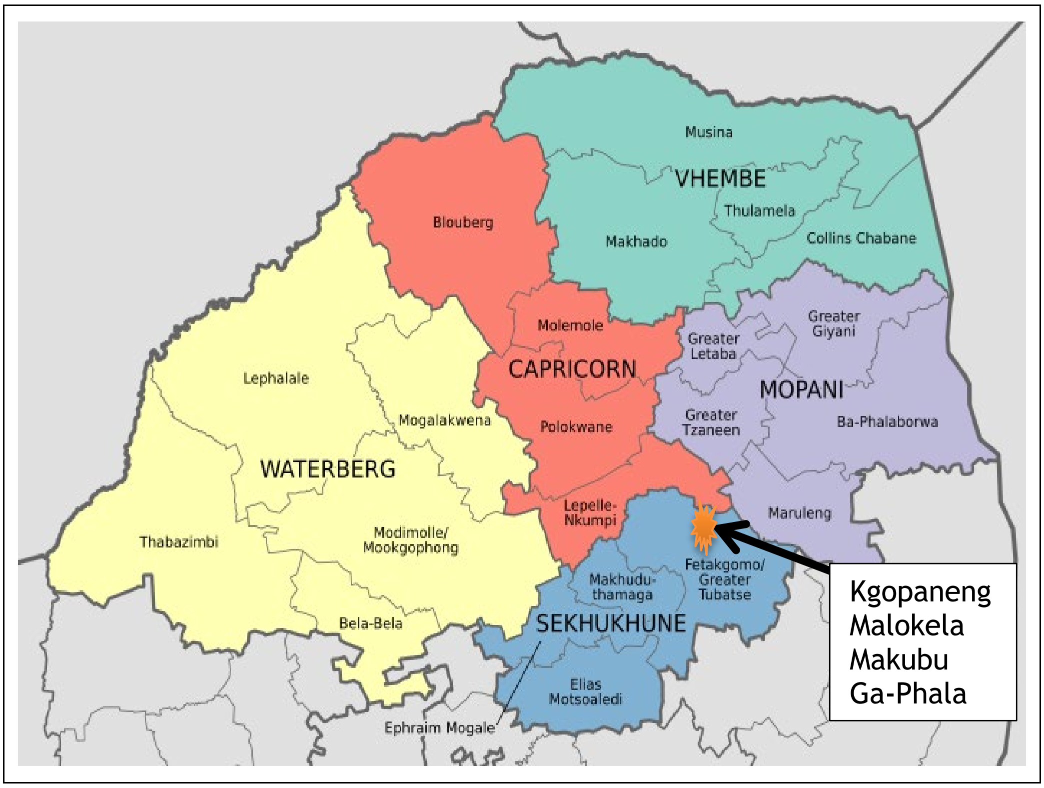

Figure 3: Map of Greater Tubatse municipality showing the location of Kgopaneng, Maloke, Makubu and Ga-Pala Villages (Anon, 2020)

3. System Dynamic Model

The increase of population and change of climate affects water availability. The rain water and groundwater are the most critical components within the water resources in rural areas. The amount of water from the ground is directly related to the water ground exploitation rate. The systems dynamic model is developed in this study to capture the interaction between water sources which involve boreholes and rain, also the domestic demand and agricultural demand as show in Figure 4. These are the main aspects that are affected due to the shortage of water. The model was developed using Vensim PLE 8.0.9 (Double Precision).

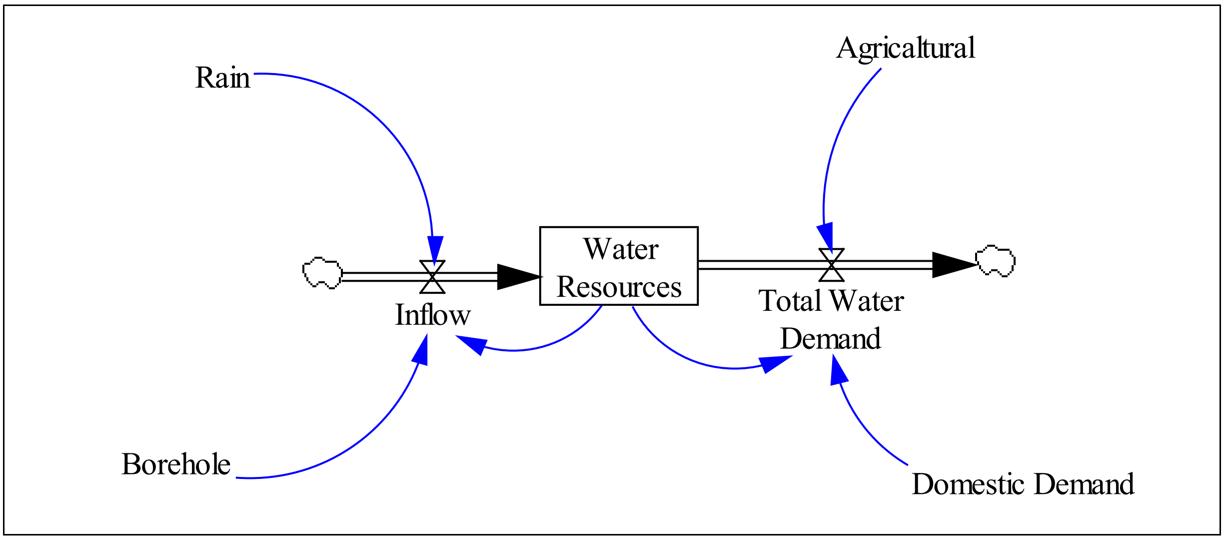

Figure 4: Stock and Flow Diagram of Water Supply in the Study Areas

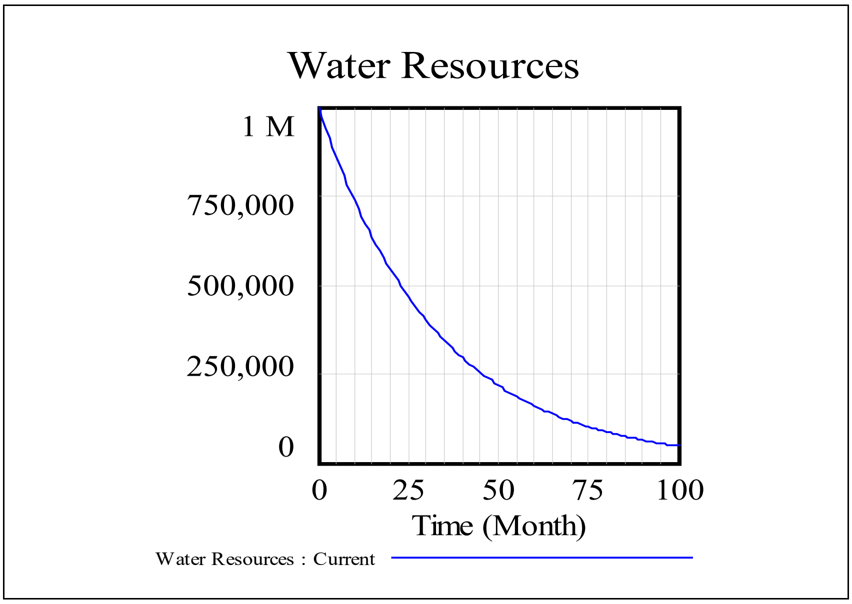

Figure 5: Impact of domestic demand and agriculture on the water resources over the period of 100 months.

Based on the existing infrastructure for water services in the study areas, it shows that there will be a gradual decrease of bulk water over the years, see Figure 5. The systems dynamic model in Figure 4 was developed based on the sources of water which are rain and borehole and also the total demand of water is mainly from domestic and agriculture sectors. There are other factors that contribute to the shortage of water which were not including in Figure 4. The population and water loses through leaks which are caused by the illegal connections contribute to the shortage of water services to the communities.

The systems dynamic model is developed in Figure 6 to determine the relationship between water sources and population in the study areas. The assumptions were made as follow;

Rain = 0.025,

Boreholes = 0.15,

Population = 7300,

Population Growth rate = 0.9.

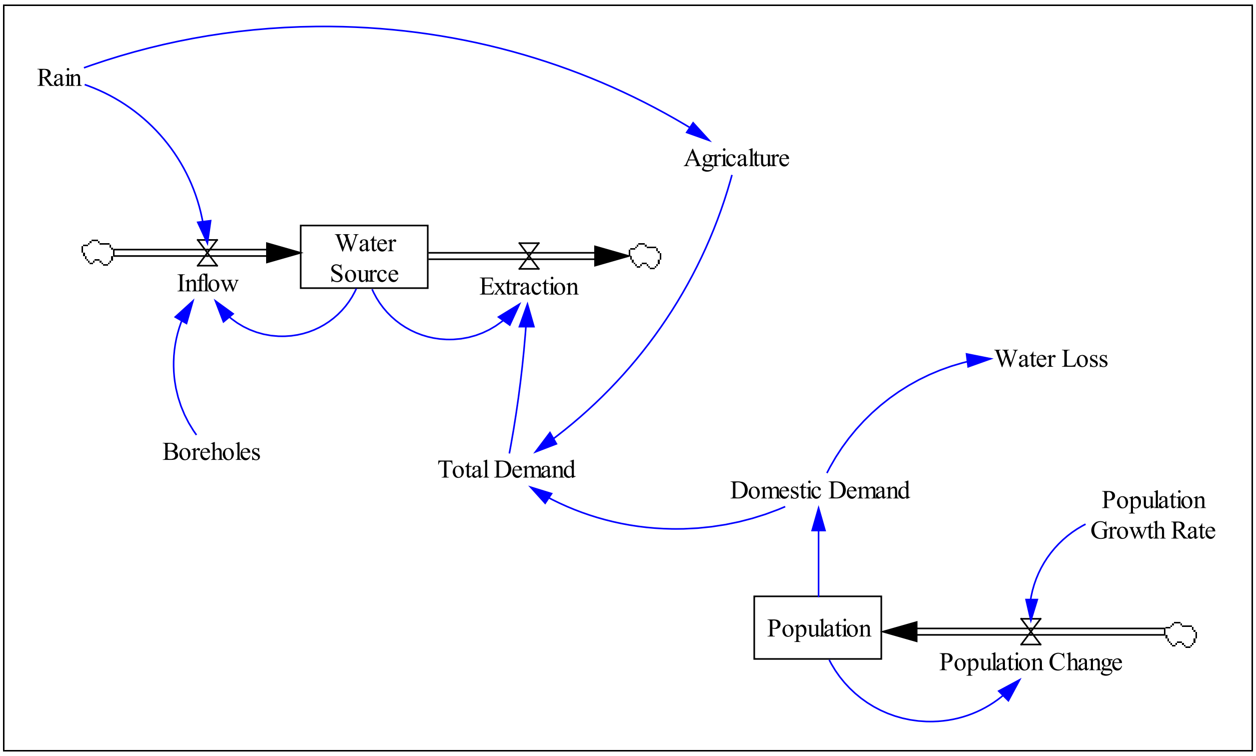

Figure 6: Stock and Flow Diagram of Source of Water and Population in the Study Areas.

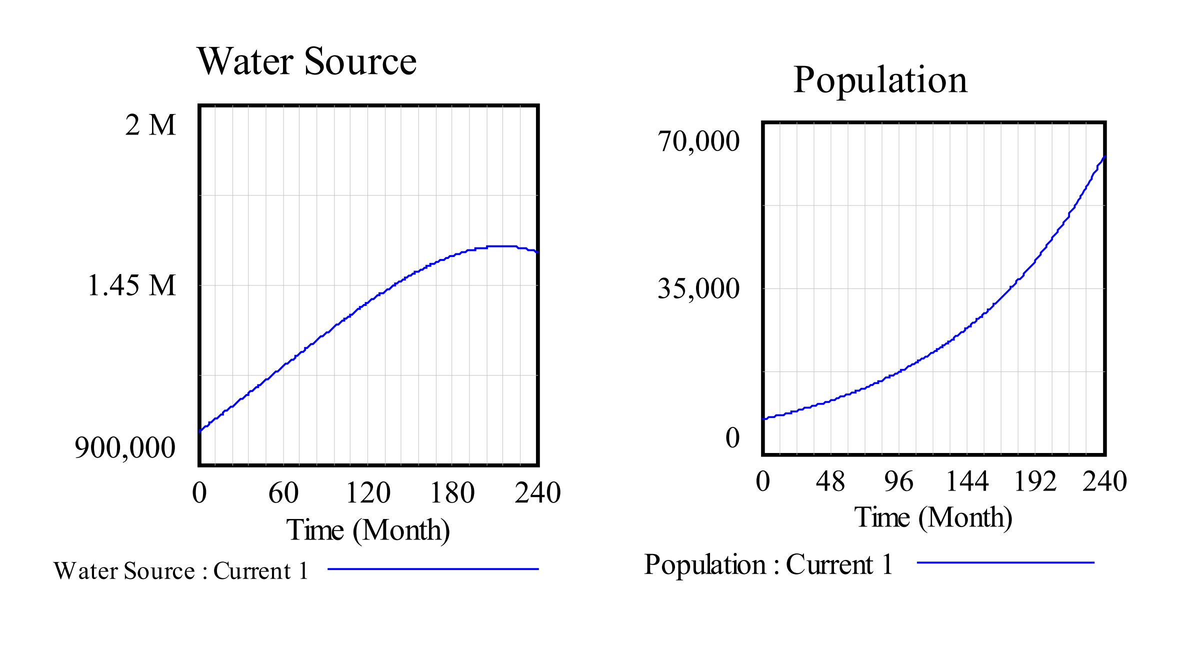

Figure 7: Relationship between the Water Source and the Population.

The relationship between the source of water and population is illustrated in Figure 7. The amount of water increases until on the 180 month whiles the population increases continuously, refer from Figure 7. This means that e failure to develop the infrastructure will cause high shortage of water in the study areas. The systems dynamic model is developed to assist with the water management and ensuring that the required demand is achieved.

4. Methodology

The study seeks to identify the communities in South Africa that are experiencing challenges in accessing water services with the intention to investigate the challenge and implement systems and strategies that will speed up the process of delivering potable water to the communities. The study aim is to conduct a checklist to observe the existing infrastructure that has been installed by the municipality in the selected areas. The focus on the infrastructure includes boreholes and pipeline for water supply. Informal interviews and questionnaires were used to gather information on these issues.

5. Findings

During the investigation, it was found that the communities do not have proper facilities to provide enough potable water. Table 2 outlines the overview of the water services of the study areas for this research. The physical observation of these areas shows that most of the villages survive with water from the boreholes. The study shows that Limpopo Province has a lot of rural areas and the service delivery is very poor.

Table 2: Overview of Water Services

Kgopaneng, Makubu, Malokela, Ga-Phala
Main source: Boreholes, Communal Standpipes, Rivers, Rain
The boreholes in the study areas are used as the main supply of water to the community. The water from the boreholes is pumped to the communities without treatment. The rain is also used as a source of water during the rainy season. Some areas suffer serious water scarcities due to shortage of resources to supply the bulk of water.

The primary source of drinking water for the communities is from boreholes and rain, see Figure 4. The municipalities in rural communities take forever to improve the infrastructures of water services as a results water sources get exhausted with time, see Figure 5. The decrease in the water supply is also due to lack of maintenance, vandalism, mismanagement of water and the increase of population. The area of study does not have Water Treatment Plant. The water from boreholes is pumped straight to the communities for consumption and domestic use. This has a higher risk to the health of the people in the communities. No water undergoes a standard treatment that includes pH adjustment, flocculation, settling, filtration, and chlorine disinfection so that the water is consumable (Matlakala, et al., 2019; Matlakala & Kallon, 2019; Matlakala, et al., 2019). The challenge of water supply in these areas is in the pumping systems. The pumping systems require proper procedures to be implemented to operate well (Matlakala & Kallon, 2019; Matlakala, et al., 2019). New settlement connects illegally (see Figure 8) on the mainline that supply the old communities, as a result, the capacity of water does not reach the designated destination. Poor maintenance of infrastructure also affects the supply of water because of water lost during the distribution period (Matlakala, et al., 2020; Matlakala, et al., 2019). The pumping system is also at risk to be damaged due to the high amount of load that it was not designed for. The study shows that for the pumping system to last longer, the load in the pumping system must not exceed the normal load (Matlakala, et al., 2019).

Figure 8: Illegal connection and leaking pipes

The system dynamics in Figure 6 is developed to assist with management of water supply and the population growth. The rate at which the population is increasing should always correspond to the service of water supply as is shown in Figure 7. The decrease of water resources in Figure 7 indicates that there should be an improvement of the infrastructures to accommodate the increase of the population.

6. Conclusion

In this study, a systems dynamic model was developed to investigate the interaction between the population and water sources in rural areas of Limpopo Province. The results in Figure 7 shows that if there is no proper type of management, the rural areas will suffer a shortage of water. It is also worth noting (referring from Figure 7) that the communities did not lack water at the beginning but due to lack of proper management there was water shortage. The study areas are facing challenges with water services range from lack of capacity, skilled people, illegal connections and droughts. The challenges affect the delivery of water services to the communities and need to be addressed with the purpose to improve the water delivery. The health of people is also at risk because of consuming untreated water. The abstracted water needs to be treated to meet the portable quality standards for drinkable water before it is distributed to the consumers. The infrastructures must be maintained regularly so that they can last for a longer period. Figure 7 shows that the demand of water supply can be increased and as the population increases this will start to decrease over the months. The systems dynamic model (Figure 4 and 6) helps with determining the population growth and management of water services. The systems dynamic model gives the opportunities to improve the water services and manage the population. The vandalism and mismanagement of water can be addressed well by providing trainings that will help with management of community facilities and water. Continues training is required to develop people in the municipalities to help with the management of the existing infrastructure and innovations that will assist with meeting the water demand of the communities.

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