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Distribution Planning Model for Water from Different Sources

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***Abstract*- Urbanization in Africa is characterized by insufficient basic infrastructure, particularly in high density areas. There is need to come up with a model which takes a comprehensive approach to urban water services and viewing water supply as a component of integrated physical system. The purpose of this study is to critically look at demand based planning model for the distribution of water from different locally available sources in the high density suburb of Budiriro as an option of supplying water for gardening, sewage system, drinking and other domestic uses to the residents. This model provides a method of integrating different sources of water to supply water according to use. The model will bring relief on water demand since the use of water from hand dug wells and Rainwater harvesting is another virgin source of water which can be exploited fully. The blending of water from different sources to come up with quality water is one of the thrusts of the model. The model provides future forecasts and scenario planning, but effective water demand should have a planning for integrated water management of the different water sources.**

***Keywords*- Model, Water sources, water demand, Recycled water.**

I. INTRODUCTION

Most cities in the world face the challenges of managing the impact and the stresses of aging infrastructure on the water supply system. An important component of any urban area, be it a city or regional centre, is the water system, providing water supply to its inhabitants.

Apparently, in many cases, the conventional approach to the provision of safe water is being over stretched due to rapid urbanization and ageing infrastructure. Urbanization in Africa is characterized by insufficient basic infra-structure, particularly in high density areas. The fact that these high density areas often do not have mature infrastructure and governance structures, and urban planning has not yet happened, means that there are real opportunities to implement innovative solutions based on the principles of integrated urban water management (IUWM) (6;15).

There is great interest in approaches to providing water systems that lower the impact on the natural environment and control expenses. In order to reorient urban areas towards sustainability, it is imperative that the different aspects of urban water systems should be viewed in relation to each other, which requires the adoption of an integrated approach to urban water system planning, provision, and management. There is need to come up with a model which takes a comprehensive approach to urban water services and viewing water supply as a component of integrated physical system, within an organizational framework.

The purpose of this study is to critically look at demand based planning model for the distribution of water from different locally available sources in the high density suburb of Budiriro as an option of supplying water for gardening, sewage system, drinking and other domestic uses to the residents. The conventional paradigm, centralized urban water supply through treatment works could supply the whole city but with the advent of urbanization they are failing to meet the required amount of water.

In the mid to late 19th century, centralization was used as a response to typhoid and cholera epidemics that swept European and American cities between the 1830s and 1870s with the centralized urban water services dramatically improving the hygiene of urban areas (4,1). The centralized water systems are facing challenges of high economic costs of rehabilitation and replacement of aging water infrastructure in highly developed urbanized areas, which in many cities are approaching the end of their useful service life. Maksimovic and Tejada-Guibert (19) state that if one looks at cities of both developed and

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developing countries, it becomes apparent that rather urgent decisions must be made with regard to the way in which urban water services are provided. This paradigm shift for a water system for different water sources distribution planning model has emphasis on demand-side management as well as supply-side management. The utilization of nontraditional water resources, that is, water harvesters, hand dug wells and boreholes, and the concept of fit for-purpose and decentralization appears in much of the literature discussing urban water and sustainability as the solution of urban water shortages.

The most significant benefit of such a model to urban water supply is the potential to escalate the range of opportunities accessible in order to be able to develop more sustainable systems. The primary aim of this model is to enable a range of options of urban water sources to improve the outcomes achieved by the system.

Development plans in these high density areas may allow direct application of radically different system structures: where different water sources are combined to supply water in urban areas. To ensure urban water security, there is a growing consensus that an integrated approach provides a better understanding of how water supply can be improved basing on the key components of urban water management including, resilience of urban water systems to global change pressures; interventions over the entire urban water cycle; reconsideration of the way water is used. It has proved difficult to develop a generic model for the management of water resources that is relevant across this diverse universe.

The 1977 United Nations Water Conference in Mar del Plata was an early effort to address water issues in a global context and perhaps the first international meeting to highlight the need to ensure that water development and management occurred in the framework of overall development policy.

It also suggested the establishment of institutional arrange -ments that would facilitate better coordination between different actors (16).

The Dublin Conference on Water and the Environment, a meeting of technical experts from primarily developed-country governments and non-governmental organizations was held in January 1992 to prepare for the Rio Summit on Environment and Development and issued a declaration proposing four principles:

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
- Women play a central part in the provision, management and safeguarding of water.
- Water has an economic value in all its competing uses and should be recognized as an economic good.

The table below shows the two approaches which have been used on the provision of water based on the centralized approach which is used in most cities developed and developing. The second is the integrated method which conjunctively uses different sources to complement each other.

Table 1. Comparison of the Centralized and Decentralized.

Centralized approach	Decentralized approach
Sources of water: surface and ground water	Alternative water sources: boreholes, hand dug wells, rain water harvesters
Same water quality for all uses	Matching quality of water with intended use
Centralized systems	Decentralized systems i.e. wells boreholes and rain water harvesters
Centralized planning	Involvement of key stakeholders

II. MATERIALS AND METHODS

1. Objectives of the Model:

- To identify the sources for the domestic and other uses water demands on the fit for purpose concept of matching water type to use.
- To provide a mathematical formula to project domestic water demand quantities
- To estimate the potential recycled water output of the model to reduce demand on domestic water demand and other uses.
- Suggest applicability conditions for the proposed model

2. The Scope of the Model:

The distribution planning model is demand focused on the distribution of adequate quantity and quality of water according to use from different sources. The scope and format of the distribution planning model is derived and explained and it follows the “fit for purpose” concept of matching water type to use in order to minimize health risk and treatment requirement.

This model uses sustainable conjunctive water resources by the use of boreholes, wells and rain water harvesting. The model uses decentralized integrated approaches that can deliver water to specific users in appropriate quantities, qualities and in appropriate times, without compromising the availability of the resources for others.

The intent of this development of the distribution planning tool is, to provide the mathematical description of the microscopic and macroscopic characteristics of urban

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water distribution planning system and evaluate the effects of waterborne diseases in the study area. In this study, the model was developed to support the distribution of water from the Municipal reticulated system with water from different local sources. The model determines water resource allocation according to quality, quantity and matching the type of water to use in order to mitigate for health risk and treatment requirements. Municipal water which needs expensive chemicals will be distributed for domestic use and less treated water will be specifically for watering the gardens. By limiting the scope of the model in this manner, the model can be general in nature and adapted to other cities with a minimum of modification.

The basic nature of the model begins with blending reticulated water from the treatment plant and water from boreholes. This is treated water which is meant to meet demand for housing units for domestic use. Water from the hand dug wells, rain water harvesters and recycled water will be used for watering gardens. A water balance analysis has been carried out to establish the level of self-reliance that might be attained using this model.

The daily water demand to assess the water sources which the residents generally regarded as their water points. This model leaves the water system being locally managed with different water sources being conjunctively used to solve the crisis and optimize the water production levels.

The procedure involves the following steps:

- The quantity and quality of water needed for domestic use from the Municipal reticulated system is blended by water from the local boreholes which would have been pumped to a reservoir and undergone treatment to meet the WHO standards.
- Using water from hand dug wells, rain water harvesters and recycled water for other uses, the model optimizes the water supply and distribution system by increasing the supply from local available resources.
- The urban water system requires a paradigm shift to a demand oriented management because concentrating on expensive water production without essential accurate water demand forecasting is rather suicidal as water use ought to be monitored as well.

For instance, authorities need to know what the water demand for today and tomorrow will be in order to operate their treatment plants and other sources appropriately to meet these demands. Authorities also need to predict the water demand 20-30 years in the future in order to develop new water sources. Some water requirements may be met by using lower quality water (untreated) or recycling water.

In addition to reticulated water, alternative sources such as boreholes, hand dug wells; rainwater harvesters and recycled water are available. The characteristics of the other sources are complex, but were extensively investigated and the quality of the water was found unacceptable for human consumption. Although a thorough review of the characteristics is infeasible, some general comments are helpful in realizing their uses in the distribution planning model.

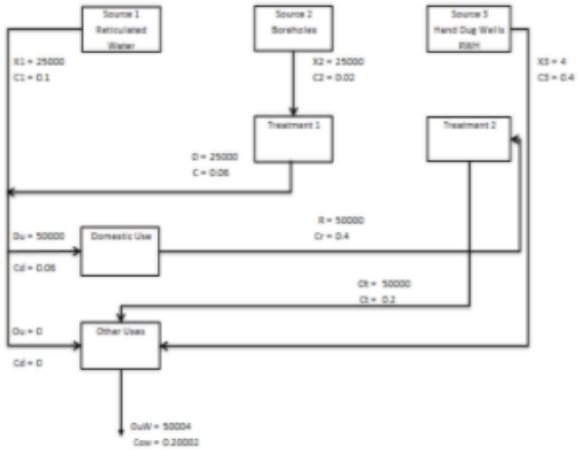

Fig 1. Schematic diagram of the distribution and planning model for different sources of water.

3. Municipal reticulated water supply:

This is one of the water sources being used in the study. The water is being supplied from a centralized reticulation system. While centralized infrastructure systems for water management have well-known advantages, they also have various disadvantages that are mainly based on an expensive and inflexible long-term building strategy. The main treatment plant for Harare, Morton Jaffray water works has been overwhelmed by urban migration with Harare having an annual growth rate of …... The water plant was originally designed for 350000 people and it was upgraded in 1994 to supply 1500000 (26), and currently the population of Harare is around 3 000 000. The supply of water is now inadequate for the increasing demand. Budiriro, the study area is currently getting a supply of 5 mega liters' of water against a per capita demand of 14 mega liters' which is a third of the per capita demand.

4. Boreholes:

The analysis of borehole water is an important part of this distribution model and the water demand for domestic use supply. The residents have been using the source as a coping option for the past 10 years and they have accepted it. The use of borehole water has several advantages than disadvantages. First, the water has less contamination and it only needs secondary treatment for it to meet the WHO standards.

Secondly, the supply of water remains essentially uniform over a season thus the water source is reliable. Third, Boreholes are not subject to evaporation generally and outflows are small, so that the ground water basin acts as a minimal loss reservoir. And finally, water quality characteristics of boreholes tend to be constant with time.

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Although groundwater pollution is a possibility usually water from boreholes is of better quality compared to surface water.

5. Hand dug wells, Rainwater Harvesters and Recycled Water:

Hand dug wells and rain water harvesters are another source of water being used in the area of study as a coping method to alleviate the shortage of water. Analysis of the water from hand dug wells indicated that the water was contaminated with total and faecal coliform and not suitable for human consumption. This source will be used to meet the garden water demand, where the water quality issue is often not of a high concern but considered acceptable in view of the intended application.

The distribution planning model incorporated this source and the water was channeled to watering gardens. This will reduce the demand from the first two sources since water from them is of better quality and also reduce the cost of treatment. The model will also provide for recycling of water from the domestic use. The water will undergo treatment before being channeled for watering of gardens. The recycled water will also provide more water to supplement seasonal sources such as harvesting of rain water which is only at peak during the rainy season. Rain water harvesting is the last source though currently it is being used at a lesser scale. Rooftop rainwater harvesting is a low technology, cost-effective, reliable source of water and should be considered as it is under used in Zimbabwe.

To promote rooftop rain water harvesting, mandatory provisions in Zimbabwe model building bye laws are necessary. In Taiwan, a new provision was added into the National Building Code where rain water harvesting for building is stipulated as necessary under specified conditions (22). Tax rebate incentives, found in Texas, Hawaii, the Caribbean islands, Australia, Germany and other European countries, are offered if the owner adds a rain water harvesting system to an existing building.

A similar study was done by Villarreal and Dixon, (18) which analyzed retrofitting rainwater collection systems in existing developments by modeling rainwater for toilet flushing, laundry, garden irrigation and car washing. It was concluded that the use of rainwater contributed to important savings in drinking water. This model is very conservative since no water is put to waste.

6. Water Distribution:

In this model two categories of water uses exist namely, domestic use and other uses which are mainly at residential level. The selection of these categories makes the model amenable to the evaluation of the system of using different sources to supply water for domestic use and the general problem in most cities in Zimbabwe. There is need to note the characteristics of the two categories of water use and discuss the assumptions employed in this distribution planning model. It investigates the characteristics of each of the two classifications of water use as it establishes the various potential decision strategies which can be a solution of shortage of water in Zimbabwe and other countries.

7. Domestic Water Uses:

Domestic water uses cover all uses of water by households, both within and immediately outside the confines of a residence. Domestic water demand may constitute well over half of the total municipal use in many communities (7). The first objective of a municipal water system is to serve the immediate needs of the residents. When the water is inadequate to meet the potential demand, important uses may be prioritized. In the ultimate limitation, water would be available for such activities as drinking, bathing, cooking and sanitation.

Hence, the domestic water uses are given first priority of the urban water system although in most areas of the study area there is no water even for these activities. The tradition is that in areas where they receive water, it is channeled for domestic uses and other outside the house uses such as watering gardens or lawns. The distribution model will look at the uses in accordance with the quality of the water. The demand management theory (13) supports the fact that water demand management is an alternative to increase water supply.

Water demand will be related to how much water is needed. A n increase in the supply will reduce the demand of water from the different sources. Domestic water uses do not maintain priority on water supply only, but its quality as well. Drinking, bathing and cooking water should meet the WHO standards and be fit for human consumption. In the model proposed herein, the philosophy has been to maintain the WHO standard limits for the water from sources one and two. This water will be specifically for domestic use.

8. Other Uses:

Other uses in this model referred to activities such as vegetable gardening, trees and lawn watering. These may be important to the living environment. Such uses are generally regarded as supplemental to the enjoyment of living in urban areas.

The urban water system water needs should be distributed on the basis of quality rather than the quantity aspects alone. By dividing domestic use and extracting other uses to be served by a poorer water quality especially with water from hand dug wells, rainwater harvesters and recycled water, more water is available to the needs with more restrictive quality characteristics.

9. Model Formulation:

The model proposed in this study has been formulated in the context of a fit for purpose distribution planning which

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can be used in any urban set up, but from a unique point of view. The model can be simplified and generalized beyond the intricate details of the physical structures of any set up.

10. The advantages are:

- The model gives room to policy change which will enhance decision making on the part of planning for better water supplies be it local, regional or at global level.
- It also helps to identify institutional constraints if optimal strategies are violated. Hence, constraints which affect long time plans are noted and mitigated at the planning stage. This will alleviate any water supply shortage since possible effects are easily noted at planning.

11. Model Constraints:

The distribution and planning model is bounded and operated by two major types of constraints: (i) Water quality constraints and (ii) water quantity constraints. The water quality constraint in effect places a WHO standard limit on the quality of water from the boreholes and the municipal reticulated which is blended from the two sources. The reticulated water would have undergone treatment from the Morton Jaffray treatment and the water from boreholes would undergo a secondary treatment to meet the WHO standards before being blended. The quality for source three which is hand dug wells; rainwater harvesting and recycled water would not the WHO standards since it will be used for non-domestic purposes.
The quantities for the model would be demand based. The major constraint would be the capacity for the reservoir to meet the supply since the drivers of demand are population growth. This will increase the water per capita demand. Currently the growth rate of Harare is at 0.79%. This will also affect the per capita water demand since it changes yearly.

12. Equations on Constraints:

Water quality constraints
TDS:

$$Cd - C_1 \geq 0 \quad (1)$$

$$Cd - C \geq 0 \quad (2)$$

$$Cd - \left[\frac{xC_1 + DC}{Du + Ou}\right]\left[\frac{xC_1 + DC}{Du + Ou}\right] \geq 0 \quad (3)$$

$$Ct_1 = \emptyset(Cd)\,\emptyset(Cd) \quad (4)$$

Ct1 is a function of Cd meaning it is dependent on Cd.
Water quantity constraints;

$$X_1 D - Du - Ou = 0 \quad (5)$$

$$OuW - X_3 - Ot - Ou = 0 \quad (6)$$

$$OuW = \emptyset\emptyset(Ou, Ot, X_3) \quad (7)$$

-OuW is dependent on flows of Ou, Ot and X3

$$R = \emptyset\emptyset(Du) \quad (8)$$

R is a function of Du, meaning it is dependent on Du

12.1 Objective Function:

Using the cost of producing quality criterion and the cost functions, the objective function can be formulated. The objection function consists of three elements:

- The cost of water supply
- Treatment, operations and maintenance cost.
- The cost of recycling wastewater to the other uses demand.

P1 is defined as the water supply cost, then

$$P_1 = X_1C_1 + X_2C_2 + X_3C_3 \quad (9)$$

C1 is the cost of getting water from X1 = $/ volume
C2 is the cost of getting water from source X2 = $/ volume
C3 is the cost of getting water from source X3 = $/ volume

The operations and maintenance cost could be determined by:

$$P_2 = 200\,Z^{0.74} \quad (10)$$

Where P2 is defined as the treatment, operations and maintenance cost The final component of the objection function is cost of recycled water which sent directly to other uses demands.
P3 = Recycle Cost (Rcr)
R is the recycle volume
cr is the cost of recycling/ volume
P3 = Rcr

The complete objective function can be expressed:

$$P = P_1 + P_2 + P_3 \quad (11)$$

13. Objective Function:

This model does not include some of the functions involved in water supply demand. For example, the costs of pumping and storage are not included since they are assumed as common to all aspects of the model.

14. Assumptions:

- It was assumed the increase in population growth is directly related to the increase in domestic and other uses water demand. In other words, there is a relationship between increase in water demand and population.
- It is assumed that the characteristics of suburbs in Zimbabwe are homogeneous hence the model can be applied nationally.

15. Validation of the Model:

For the validation of the model to calculate the per capita water demand per person, the population of Budiriro and the growth rate for Harare are used. Budiriro has a

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population of 138146 and the growth of Harare according to United Nations World Population (27) varies annually. From such data the model looked at the period from 2016 to 2026 with the domestic water demand per capita for 2016 found to be 9670220 liters'. The subsequent years is given in the table. The demand for other uses is also calculated using the number of housing units in Budiriro which is 25300. The demand per housing unit, for watering gardens was calculated using figures acquired from literature of 100 liters' per housing unit. The total demand for the housing units is 2500000 liters. The water for other uses is collected from recycled water and hand dug wells.

Comparatively, the demand for watering gardens and water to be recycled show that excess water can be realized by this model. The model shows that as the population growth rate increases there is more water produced for recycling hence lessening pressure on hand dug wells of which recycled water can sustain other uses on its own.

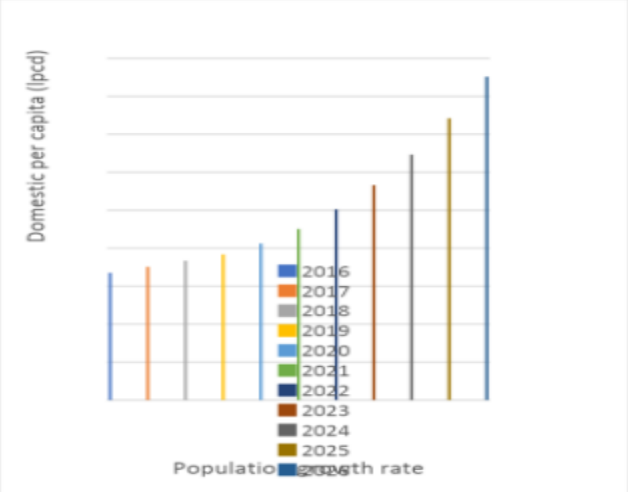

Fig 2. Population growth in relation to water demand.

16. Application of the Model:
There are several factors which influence water demand in Zimbabwe. most cities and high density areas have the same characteristics. In this study, population growth rate, domestic water demand, climate change and water supply are regarded as in put data which influences domestic water demand. The population is a function of urbanization which is a key factor in water demand as people move to urban areas thereby straining the limited water resources. The model will be applied in Budiriro high density suburb which is in Harare the capital city of Zimbabwe. The suburb has inadequate water supply with some areas going for years without domestic water supply. This has resulted in the area being prone to waterborne diseases such as cholera and typhoid, with the latest outbreak that was recorded in 2019. According to the City of Harare Department Statistics, (24), Budiriro has a population of 138146 people with more than half not receiving reticulated water throughout the day.

17. Input Data Population Growth:
Population growth is one of the factors used in this model as a key determinant of domestic water demand projections. The population for Budiriro for 2016 was used as the basis and the annual growth rate from the United Nations World Population 2019 was used to calculate projections. Figure 2 below illustrates the impact of population growth rate to water demand in Budiriro. The growth of the population greatly determines the volume of domestic water required According to WHO. Between 50 and 100 liters' of water per person per day are needed to ensure that most basic needs are met (25).

18. Domestic Water Demand:
Domestic water demand knows various interpretations and also varies widely per area. In this model, it is calculated from the total population multiplied by the daily per capita water demand that does not include industrial demand. The demand focus of this model was based on the population and liters' per person per day to come up with the actual demand. For this model 70 liters' per person per day was used to calculate the per capita demand 50 liters' is usually used for rural areas where there is no water flushing system. Other uses are calculated separately since this demand is supplied from a different source, working with an individual housing unit's demand.

19. Climate Change:
Climate change is projected to substantially reduce available water in many of the water-scarce areas of the world (21). Climate change brings about measurable changes in temperature, rainfall or wind patterns, among others. These effects are being felt now in Harare where the rainfall patterns have drastically changed. Fig 1 below shows the variability seasonal rainfall in Zimbabwe since 1901, shown by the zigzagging line.

The red line indicates the average rainfall gradually declining. This is attributable to natural and human induced climate change. This pattern has affected even the availability of surface water with most dams not receiving enough of it. Harava dam which supplies water to part of Harare has dried leading to the decommissioning of Prince Edward treatment plant. These are some of the results of climate change.

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Fig 3. Zimbabwe average seasonal rainfall (mm) 1901/02 to 2009/10.
Source: Meteorological Services Department of Zimbabwe

III. RESULTS

1. Domestic Water Demand:
The model projections show the gradual increase of the domestic water demand as population growth increases. The population growth rate is not static. The projections are that it will be gradually increasing indicating a rise in domestic water demand. Table 4 shows figures from the input variables indicating projections from the distribution and planning model. Calculations to show the period after 2026 into the future can be presented using population growth rate.

Table 2. Results of the projections by the model on per capita domestic demand.

Year	Population	Per Capita Demand Lpcd	Population Growth Rate %	Per Capita Domestic Demand litres
2016	138146	70	0.33	9670220
2017	138601	70	0.33	9702070
2018	139058	70	0.33	9734060
2019	139614	70	0.40	9767050
2020	140438	70	0.59	9824655
2021	141533	70	0.78	9901290
2022	143004	70	1.04	10004260
2023	144834	70	1.28	10132314
2024	147122	70	1.58	10292380
2025	149873	70	1.87	10484848
2026	152990	70	2.08	10702965

As an illustration the model was used changing the three inputs, population growth, water demand and the climate change the target was to see the increase in the water demand. In the linear graph figure 2 there is a demonstration to illustrate the projections of water demand for the period 2016 to 2026.

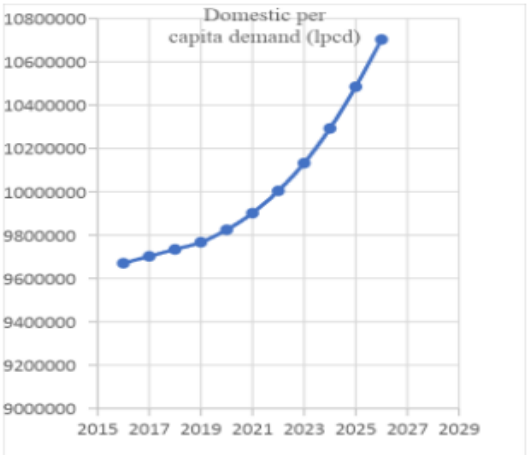

Fig 4. Projections of domestic water demand.

2. Other Uses:
On the water demand for other uses, the number of housing units in the seven areas of Budiriro is 253000 according to the Department of Housing report. The water demand for other uses according to literature shows that for watering gardens 100 liters' are required per housing unit. The total per capita per for all housing units per day is 2500000 liters'. The water channeled from the domestic use to be reclaimed is shown on table3. If half the amount is reclaimed there will be excess water for other uses. This amount increases as the population growth rate increases so this entails that there will be enough water. Figure 4 shows the demand from other uses in relation to the quantities available indicating a surplus in recycled water which can ease the pressure on domestic water demand if the water is treated to the required WHO standards

Table 3. Results of the projections by the model on other uses demand.

Year	Housing Units	Demand for Other Uses	Waste water To be recycled litres
2020	*25300*	2530000	9824655
2021	25300	2550000	9901290
2022	25300	2530000	10004260
2023	25300	2530000	10132314
2024	25300	2530000	10292380
2025	25300	2530000	10484848

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Table 3 above illustrates how this model can be a solution to the water problem. Currently in 2020, the demand for water for other uses is 2530000 liters' against 9824655 liters' for recycling hence resulting with an excess of 7294655 liters'. The case study of Singapore is a good example under its four taps strategy, it uses a range of measures to improve water use efficiency, curtail waste, diversify the water supply and manage water demand. They have used the membrane water based purification which has enabled large scale production of reclaimed water (NEWater). Since the production of NEWater the take up rate for human consumption and non-domestic use has increased. This technology can save the City of Harare on production cost since this will be done locally. Using the distribution planning model in conjunction with the Singapore technology the problem of water can be easily solved.

IV. CASE STUDY SINGAPORE

Singapore has led efforts to treat sewage to a standard that allows it to be used for drinking purposes. Although the process is currently energy intensive (17), technological advances are making direct potable reuse an increasingly cost-effective solution (12). The water management solutions of Singapore have evolved over several decades and clearly reflect its unique circumstances as a small city state. Nevertheless, the principles that underpin its water management offer lessons for other cities and countries.

Under the Four National Taps strategy, Singapore uses a range of measures to improve water-use efficiency, curtail waste, diversify the water supply, and manage water demand. Singapore relies on advanced technologies. Membrane-based water purification has enabled the large-scale production of reclaimed water (NEWater). Since production began in 2003, the take-up rate of NEWater for human consumption and nondomestic use has increased steadily, thanks to its low cost and high quality. The water utility ensures reliable supply by drawing on alternative sources and supplying customers with storage tanks.

V. DISCUSSION

The distribution planning model is a demand focused tool which points out that the future urban demand is mainly driven by population growth, climate change and changes in per capita domestic water demand. The introduction and utilization of this model by the city of Harare will assist the authority with the basis for provision of adequate water supply using locally available sustainable resources. This model provides a method of integrating different sources of water to supply water according to use. In particular, it exploits the significant amounts of water from different locally available sources by blending reticulated water and borehole water to come up with quality water for domestic use. Water which is recycled is treated to meet the less water quality demand of watering gardens.

The case study scenario of Singapore can be exploited in future by purifying reclaimed water to NEWater for human consumption and non-domestic use in Zimbabwe. Figure 3 shows that through this model there is more water for recycling than the intended use of water gardening. Wastewater represents one of the few readily available sources of water, particularly in arid and semi-arid areas (23).

The model will bring relief on water demand since the use of water from hand dug wells cannot be necessary since there will be enough water. Rainwater harvesting is another virgin source of water which can be exploited fully. This model included it although in Zimbabwe it's still not mandatory in the building by-laws in countries such as Rwanda, Australia, Taiwan they are harvesting water at household level. Rainwater harvesting is a low technology, cost effective reliable source of water supply and should be seriously considered.

The model requires the support of policy and legislation for its effective implementation. A good example is on rainwater harvesting, which should be enacted in the building and housing Acts so that incentives will be awarded for installing the gadgets. The Mathematical estimation of the model may lead to a better projection of future per capita domestic demand.

VI. CONCLUSION

This model takes the fit for purpose concept and it is applied in the demand focus of the distribution of water from different sources. The blending of water from different sources to come up with quality water is one of the thrusts of the model. The future projection of per capita domestic water demand can be done with limited accuracy due to the ever changing population growth rate. Unforeseen natural disasters such as the covid-19 pandemic may happen and reduce the population but would not significantly impact the envisaged plans.

The model has managed to integrate water from various sources namely, boreholes, hand dug wells, municipal water, rain water harvesters and recycled water into one system while maintaining social values with respect to risk and amenity.

Although the model may have limited accuracy, it is important and essential to have an estimate of future trends for planning purposes. The model also assists to project the necessary daily per capita water demand resources required. The model provides future forecasts and scenario planning, but effective water demand should have a planning for integrated water management of the different water sources.

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