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THE CITY OF Bulawayo is the second largest city in Zimbabwe with a population of about one million and is the major industrial hub for the southern region. The region is characterized by poor rainfall and has experienced its worst droughts in living memory. The average annual rainfall is 640mm and water rationing and restrictions have been the means of supply. This research is aimed at finding solutions to the current water shortages and possible ways of improving efficiency in supply and distribution system. The main objectives of the research are to evaluate current sources of supply and to estimate water losses in the distribution. Recommendations were made on ways of improving efficiency in supply and possible future sources were identified.

Present sources of supply and demand

The present supply of water is derived from five reservoirs and augmented by underground water from the Nyamadhlovu aquifer, which has a pumping capacity of 26000m^3/day. The total designed reservoir capacity of the five reservoirs at full supply level is 363 x 10^{3}m^3 with a 4% safe yield of about 174 x 10^3 m^3/day (Ministry of Water, 1998). The catchment area drained by these reservoirs is 3985km^2. The per capita demand is shown in Table 1 and 60% of this demand is estimated to be for domestic, and 40% for industrial and commercial purposes (MZWAP, 1996).

Due to the severity of the droughts in this region, restrictions and water rations on water consumption were imposed since 1938. This has resulted in a suppressed demand of 110 litters/ca.day almost a reduction of 50% from the potential demand of 222l/ca.d if there were no restrictions. The actual demand between 1977 and 1997 and the potential trend line for water demand projected to year 2020 are shown in Fig. 1. The area between the potential and actual demand shows the short fall in water supply (suppressed demand). In other words, if there were no restrictions due to the current shortages, the existing water consumption will be equivalent to the potential demand. It was assumed that the present suppressed demand will be in place until such a time when a reliable new source is found and is expected to be in place by the year 2006.

Water losses

Evaporation is by far the major cause of water losses in impounding dams and especially for this semi arid region. A direct method was used to assess the evaporation losses. A US Class A pan was used and daily evaporation data as from 1963 to 1996 was analyzed for each dam. The total annual evaporation losses were estimated from (Subramanya, 1991):

$$V_E = AE_{pan}C_p \qquad (1)$$

Where:

A	=	Average annual reservoir area, m^2
Epan	=	Pan evaporation, m
C_p	=	Relative pan coefficient (@ 0.7)

The unaccounted treated water in the distribution systems is made up of transmission losses from the treatment plant to storage reservoirs and losses in the distribution. The losses were calculated from the difference between the treated water at the treatment pant from the actual water consumed as reflected on the water bills as from 1990 to 1996. Almost all the consumers in the City of Bulawayo are metered and the billed amount was based on the figures from the meter readings, which are carried on a monthly basis. In this research meter inaccuracies, measurement errors and thefts were assumed to be small and therefore ignored. Also time errors due to time-distortion effects were ignored since the time period was long and the reading pattern is regular thereby making them self-compensating. The summary of the losses for the period under study is shown in Table 2. In the table, the treated water represents the total amount of water treated from Criterion and Ncema Waterworks and is the amount which was pumped into the distribution system.

Results and discussions

The average annual pan evaporation for the five supply reservoirs is 1.834m giving a total average annual losses due to evaporation of 55.89x10^{6}m^3 per annum. These losses represents 15% of the total designed full supply capacity.

The annual losses are shown in Table 2 and the total average distribution losses for the entire period under study amount to 19.4% of the treated water and these are high. Besides evaporation and distribution losses, there are also losses due to siltation of the reservoirs. For the five supply dams, the estimated loses due to reservoir sedimentation is estimated to be 0.24% of the total designed full supply capacity. In a best-managed system, distribution losses

Table 1. Design per capita demand

Type of use	per capita demand (l/ca.day)
Domestic	133
Industrial	30
Commercial	15
Public use	34
Wastes and thefts	10
Total per capita demand	**222**

Source: Matebeleland Zambezi Water Project (1996)

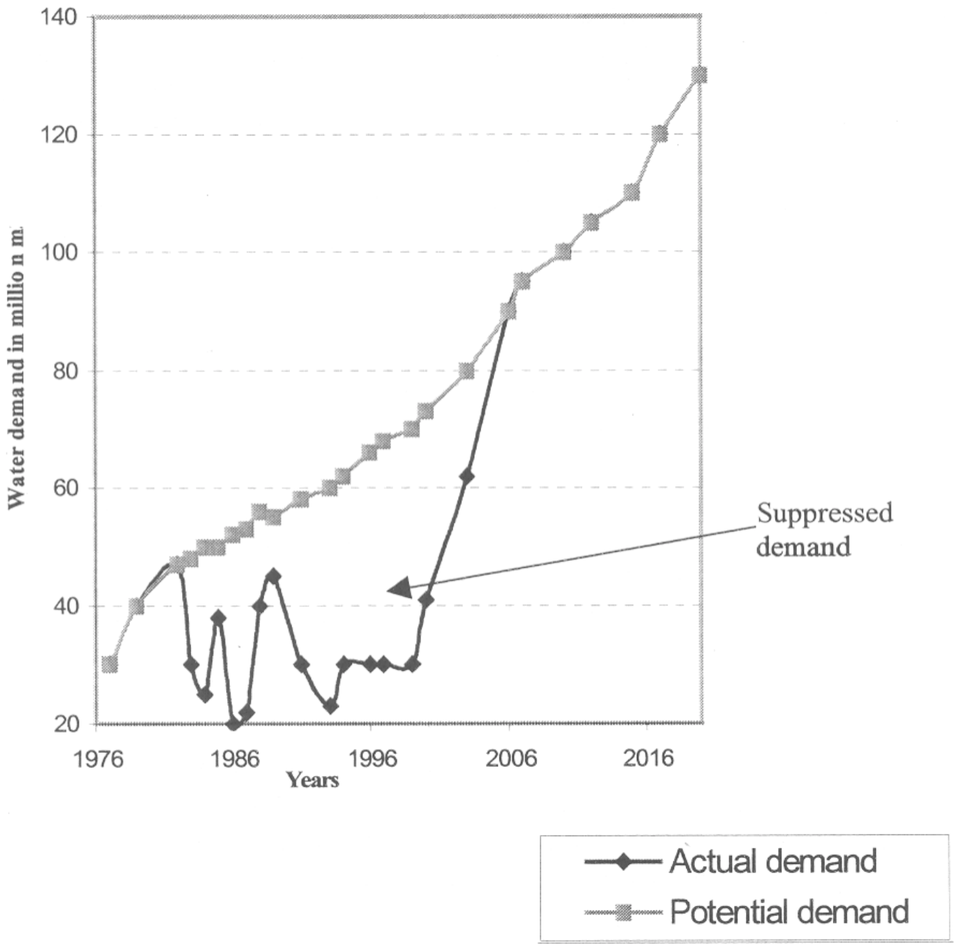

Figure 1. Actual and potential water demand

Table 2. Total treated and actual consumed water

Period (yrs)	Amount consumed (x $10^6 m^3$)	Amount treated (x $10^6 m^3$)	% losses
1990	33.43	40.50	17.5
1991	26.02	32.76	20.6
1992	19.65	24.19	18.8
1993	25.79	32.94	21.7
1994	25.68	32.50	21.0
1995	23.65	26.78	11.7
1996	24.45	32.44	24.6

amount to 10% and may be as high as 40% in a faulty system. The distribution losses amount to a loss in revenue of about Z$10million per month. The major cause of these distribution losses is due to pipe bursts and on average about 12000 burst pipes are recorded in the City per month.

Practically it's difficult to reduce evaporation losses. Siltation losses though small require long term conservation methods on an integrated catchment management. The distribution losses, which are the highest, can be easily overcome. A 5-10 % is classified as low, a 10-20% is unsatisfactory and action is desirable. Anything over 20% requires an urgent remedial action and this is the case with Bulawayo.

Conclusions

The present water rationing in the City of Bulawayo is a result of inadequate water supplies from the existing sources. This situation is exacerbated by high distribution losses above the recommended values due to poor system management by the local authorities. The percentage of unaccounted water in a system has become a measure of not only the physical condition of the system but of the system management as well. Against this background, priority should be given to the reduction of these distribution losses as a way of improving and effectively managing the current water resources. This can be achieved through establishing a reliable leak detection system to detect leaks within a shortest period of time and to be followed by repairs. Besides cutting down distribution losses, long-term reliable sources need to be examined like the Zambezi Matebeleland Water Project to be exploited in conjunction with other groundwater aquifers.

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