THE HYDROLOGICAL CHARACTERISTICS OF THE FUKUOKA DROUGHT OF 1978 AND THE POST DROUGHT WATER RESOURCES MANAGEMENT

Kenji Jinno, Akira Kawamura
Department of Civil Engineering(SUIKO), Faculty of Engineering, Kyushu University, Fukuoka, Japan 812

Toshihiko Ueda
Department of Civil Engineering, Faculty of Engineering
Kyushu Kyoritu University, Kitakyushu, Japan 807

Nobuji Takeoka
Water Resources Planning Agency of Fukuoka Prefecture, Fukuoka, Japan 812

Abstract

Fukuoka City, a fast growing economic and cultural center in Kyushu, Western Japan, experienced a severe drought in 1978 resulting in water rationing which lasted for 287 days. This drought warned that Fukuoka City is vulnerable to water shortage unless the management of water resources meets appropriately the water demands due to the growth of the population and industry. In this paper the record of precipitation and change in the reservoir storage which characterized the hydrological background of the drought are described. The impacts caused by the drought and the countermeasures taken by the governments during and after the drought are also introduced.

1 Introduction

People living in an urbanized areas may feel that water should be supplied as much as they need unless they experience a drought long enough to forget its inconvenience. Even urban planners are often unaware of taking into consideration that water resources is one of the indispensable constraints for appropriate development of a city. The Fukuoka drought happened in 1978 when the people were believing that much water consumption would be a barometer of modern city life.

In the following sections, the outlines of the Fukuoka drought in 1978 and the water resources management are explained.

2 Water resources in the Fukuoka Metropolitan Area before the drought

Fig. 1 shows the recent water resources of Fukuoka City. We observe that the mean daily water supply before the drought in 1978 increased rapidly. Then, it decreased drastically after the drought. In spite of more annual precipitation in the last decade than in the decade of the drought, the mean daily-individual water supply has not been increasing since that drought. On Table 1, the municipalities in the Fukuoka Prefecture which rationed water are shown together with the hours of water supply per day. The area affected by the drought is shown in Fig. 2. The municipalities that suffered from the drought are depicted by closed circles. At the bottom of the figure, the populations of the municipalities in the year of the drought are shown. Except two towns near Fukuoka City, seven municipalities suffered from the drought.

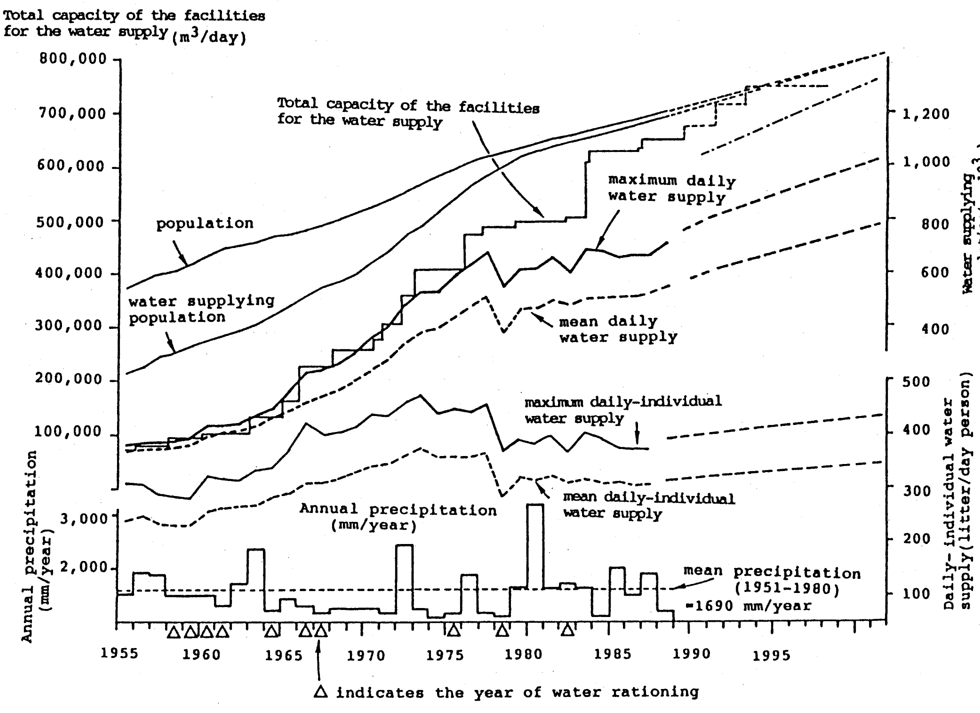


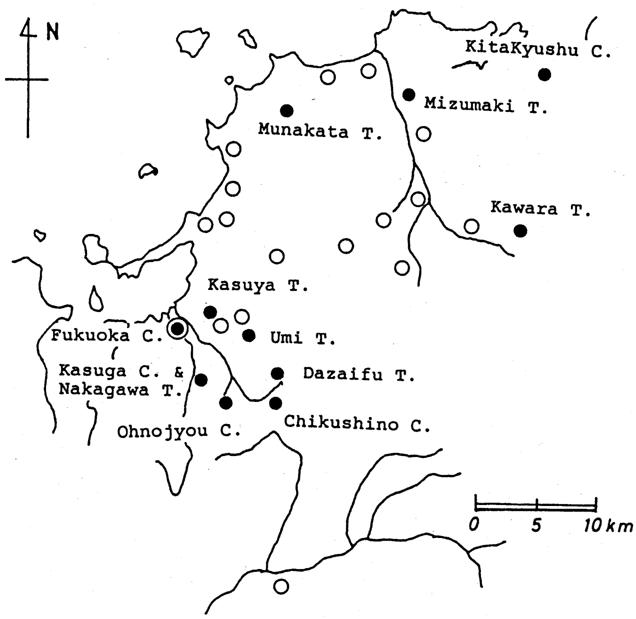
Fig. 1 Transition of the water resources since 1955

3 Water intake system

The biggest river closed to Fukuoka City is Chikugo River managed by the state. Other smaller rivers are managed by the prefectural government. They are Zuibaiji, Muromi, Naka, Mikasa and Tatara. Unlike Chikugo River, these rivers do not have sufficient and stable

Table 1 Municipalities rationed the water supply during the Fukuoka drought(number equals hours of water supply per day)

Name	1978								1979		
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Fukuoka C.	15 9	5 16	10	8	6	7	9	9	12	12	18
Ohnojyou C.	14	8		14	14						
Chikushino C.	14	6		15							
Kasuga C. & Nakagawa T.		16		14							
Dazaifu T.	6			12	6	6	16	18			
Kasuya T.				15	15						
Munakata T.				12	9						
Umi T.		16			16						
Kitakyushu C.		15	15	15	11	14	15	15			
Mizumaki T.		15	15	15	11	14	15				
Kawara T.		16	16	16	16	16					



Municipalities and the populations rationed the water supply during the Fukuoka Drought

	population		population
Fukuoka C.	985,000	Ohnojyou C.	52,100
Chikushino C.	30,000	Kasuga C. & Nakagawa T.	62,100
Dazaifu T.	26,600	Kasuya T.	14,000
Munakata T.	33,500	Umi T.	19,500
KitaKyushu C.	1,042,000	Mizumaki T.	25,000
Kawara T.	8,400		

Fig. 2 Municipalities suffered from the drought

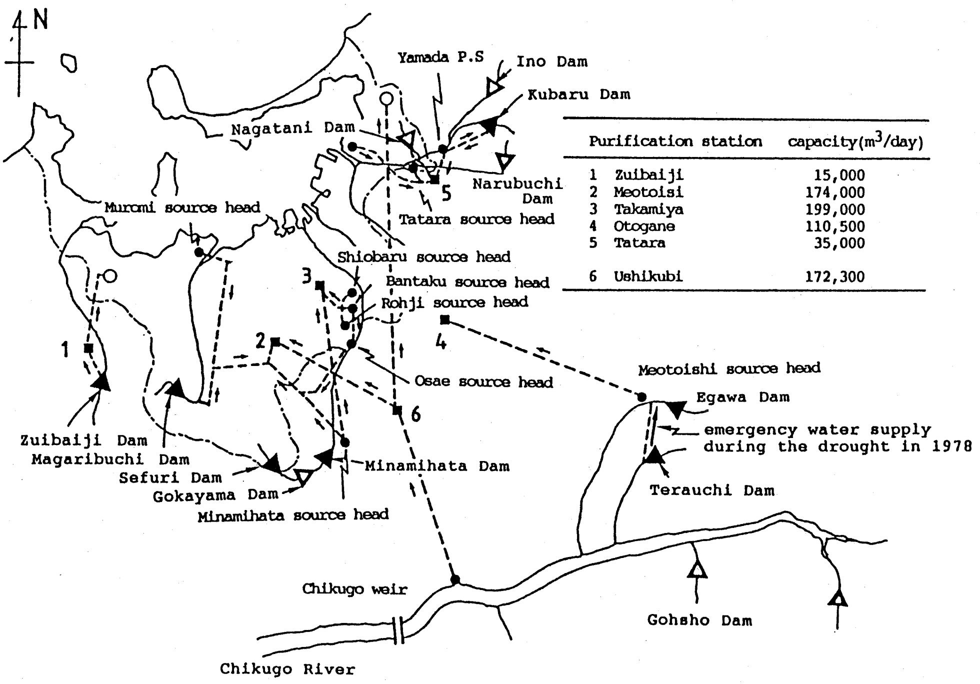


Fig. 3 Water source and conveyance system to Fukuoka City

discharge due to the small catchment areas. Fig. 3 illustrates the water transfer system;closed and opened triangles depict the completed and planned dams respectively, squares the purification station, closed circles the water source head, and broken lines the water conveyance pipelines. The purification stations belonged to Fukuoka City are listed at the top right of the figure. These purification stations had their own supplying areas in the city and were operated independently before 1978. After the drought, the project for the mutual water supply was started. This project was conceived due to the fact that the poor recovery of the Egawa Dam delayed the water supply from the Otogane purification station and this resulted in long term water rationing. Table 2 shows the attributions of the dams supplying water to Fukuoka City. It would be clear that the poor recovery of the Egawa Dam is resulted from its small catchment area in spite of its big storage capacity.

4 Hydrological characteristics of the drought

A ninety year record of the annual precipitation is plotted in Fig.4.

Table 2 Dams supplying water to Fukuoka District

Dam	Catchment area(km^2)	Capacity (million m^3)	Purposes	Jurisdiction
Zuibaiji	7.2	2.270	F C	Fukuoka Pr.
Muromi	11.4	2.368	C	Fukuoka C.
Sefuri	5.5	4.401	C	Fukuoka C.
Minamihata	27.5	5.560	F C	Fukuoka Pr.
Kubaru	0.9	1.460	C	Fukuoka C.
Egawa	30.0	24.000	Ir C In	Corp. of WRD.
Tearauchi	51.0	16.000	F Ir C	State
Yamagami	9.1	2.980	F Ir C	Fukuoka Pr.
(Under Construction)				
Nagatani	1.8	4.740	C	Fukuoka C.
Ino	5.5	4.910	F Ir C	Fukuoka Pr.
Narubuchi	6.8	4.160	F Ir C	Fukuoka Pr.
Ushikubi	4.4	2.100	F C	Fukuoka Pr.
(Planning)				
Gokayama	18.9	39.700	F Ir C	Fukuoka Pr.

F:Flood control C:City water Ir:Irrigation In:Industry

Roman numbers specify the epochs divided by the abnormal detection index which is calculated by the likelihood ratio of two sets of probability density functions of the residuals from the regression time series model. Details for this analysis are shown by A. Kawamura et al(1986). The capitals A, B and C characterize the type of the monthly precipitation ; A indicates the year when drought happens due to low monthly precipitation which continues over a year, B the year when high precipitation continues over a year and C the year both high and low monthly precipitation occur in a year alternatively. The mean annual precipitation of each epoch fluctuates as shown in the figure. The variation in the mean value of each epoch would be associated to long term variation in the precipitation. The storage capacity of reservoir is commonly planned using a river discharge record whose return period is equal to ten years. Therefore, the storage efficiency of a reservoir is dependent on the record length. If a short record of the precipitation is used disregarding long term variation, then there is a possibility that the efficiency of storage would be low(A. Kawamura et al.,1987). Fig. 5 shows the non-exceedance probability of the annual precipitation plotted on a normal probability graph. The normal distribution seems to be adaptable except with the high and low ranges of the precipitation. Simple extension of the non-exceedance probability in high and low ranges may

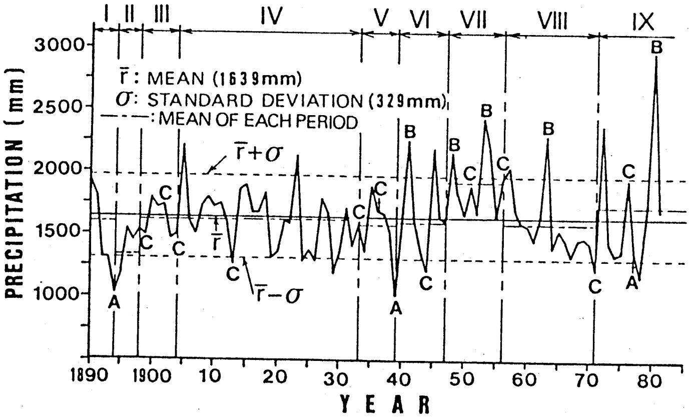


Fig. 4 Annual precipitation record in Fukuoka City

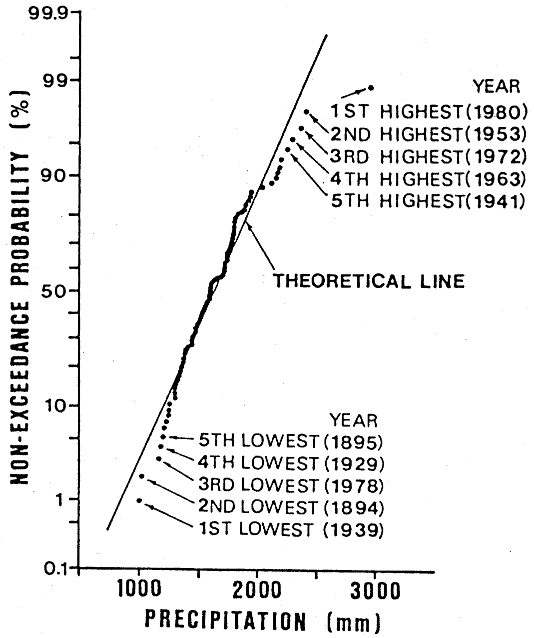


Fig. 5 Non-exceedance probability of the annual precipitation

estimate unrealistic probability of occurrence. The total precipitation for six months from September of 1977 to March of 1978 is 58% of normal and the total precipitation for the three months from March to May was less than 50% of normal. Table 3 shows the normal variation in the reservoir storage and the comparison of the storage transition in 1978 with some specific years. Generally speaking,

Table 3 Summary on the reservoir storage

Trend of reservoir storage for the ordinary year

winter	April-May	June	summer	September
drought period, minimum storage February to March	increase of storage due to Natane Tsuyu*	maximum storage due to seasonal rain front	decrease of storage due to increase of demand	increase of storage due to typhoon

*"Natane Tsuyu":The rainy season during colza cultivation

Change in the reservoir storage

	1970	1975 and 1976	1978
percentage of storage volume(%)	10% at the end of March ↓ 70% in April	25% in mid February ↓ 65% in May	25% in mid February ↓ less than 20% in May

Rainfall of 215 mm on June 10

↓

Total rainfall for July to September : 269.5 mm ⇄ Average rainfall for July to September : 650.6 mm

↓

Total storage rate on September 15 : 6.94%

winter is the low precipitation season, spring from March to April and summer from June to August are the high precipitation seasons. The storage recovery is expected in spring and summer. The increase in the water demand in summer reduces the storage. In the typhoon season much precipitation is received and this is enough for the storage recovery in an ordinary year. Compared to the ordinary year, recovery of storage of all reservoirs in 1978 was very poor. Specifically the storage in mid September was only 6.94% of normal. In Fig. 6 the plots of the variations in storage and of the monthly precipitation are illustrated. The monthly precipitation in 1978 shown by a solid line was lower compared to the mean precipitation by a broken line. Only the precipitation in June of 1978 was more than that of the average year. Because of the much precipitation, the water rationing was

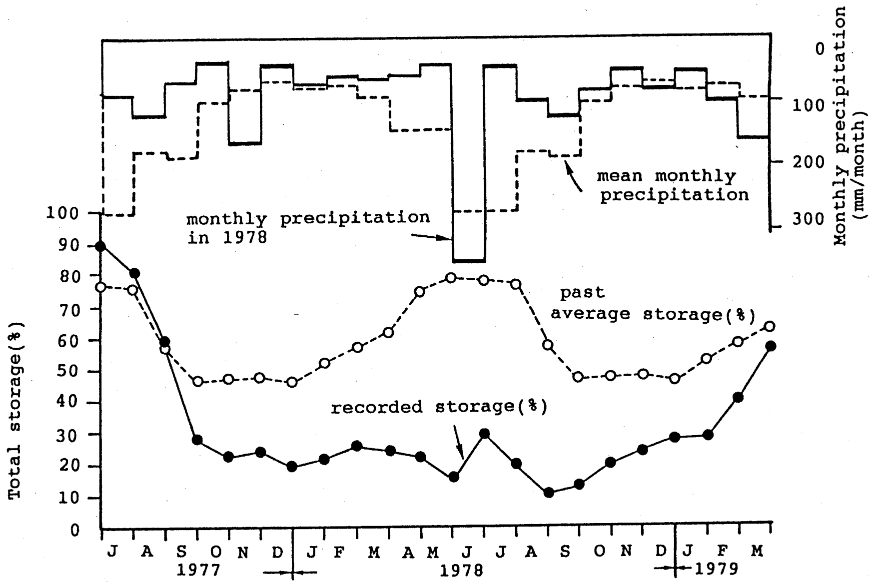


Fig. 6 Variations of storage and precipitation

relaxed and supply time was increased to 16 hours from 5 hours at the end of June as shown in Table 1. The solid line with closed circles indicates the variation in the storage rate of all reservoirs. Even though there were many discussions on the reservoir operation that the Fukuoka City government took during the drought, the lack of precipitation in 1978 should be the most dominant cause of the drought. Considering the difficulty in predicting long term climatological variations, it would not be an easy task for the frontal engineers to optimally manage the vulnerable water resources of an expanding city. Table 4 is the total supplementary budget spent for the drought. This urgent investment was equivalent to 24% of the budget of a normal year.

5 Water resources developments

Because of the geographically disadvantaged area and low water resources, several unique water resources have been developed to meet the demand of the higher population in the Fukuoka area. Fig 7 shows the project at Rohji completed in 1969. Only the net duty of water has been supplied by pipelines. A similar project was also introduced at Osae in 1979. By using this system, the city government was able to increase the water supply of 70,000 m^3/day because the agricultural

Table 4 Supplementary budget for the drought by the Water Supply Agency of Fukuoka City

*Transportation of city water by trucks *Manual valve operation *Construction of common water supply faucet	780,000,000 yen
*Installation of water saving pins *Water conservation campaign	130,000,000 yen
*Survey of water resources in Tatara River Basin	100,000,000 yen
*Construction of water intake station from Muromi River	1,150,000,000 yen
*Installation of pumping station *Construction of water distribution pipeline	690,000,000 yen
*Improvement construction of Magaribuchi Dam	150,000,000 yen
Total	3,000,000,000 yen

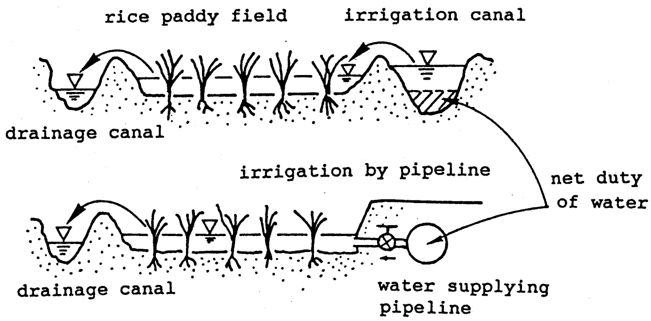


Fig. 7 Supply of irrigation water by pipelines

consumers did not use the unnecessary water. Fig. 8 illustrates the transfer of the river water to the Kubaru Dam. This project started in 1971. As the attribution of the Kubaru Dam is shown in Table 2, its catchment area is small and this is almost equivalent to the dam surface area. The purpose of this kind of dam is to store the water transferred from another river during the non irrigation period. A similar dam, the Nagatani Dam, is now under construction. Fig. 9 shows the transfer of the treated water from the sewage station built in the Mikasa River drainage area to Naka River for industrial use and that the city intake is upperstream of the system. Because of this system, the Fukuoka City government was able to increase the water intake by 17,000 m^3/day in 1985. Fig. 10 shows a water saving pin which prevents wasting water by controlling water flow. Fig. 11 illustrates the use of recycled water from the sewage station for non drinking purposes. This system started in 1980 and is supplying the recycled water in the amount of 3,000 m^3/day to the area of 320 hectares. Fig. 12 is the remote control system for the water distribution. Since the manual valve operation during the drought

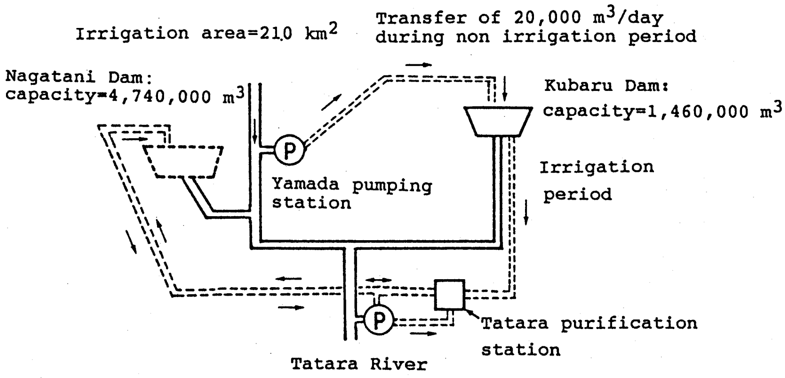


Fig. 8 Transfer of the water during non irrigation period to Kubaru Dam

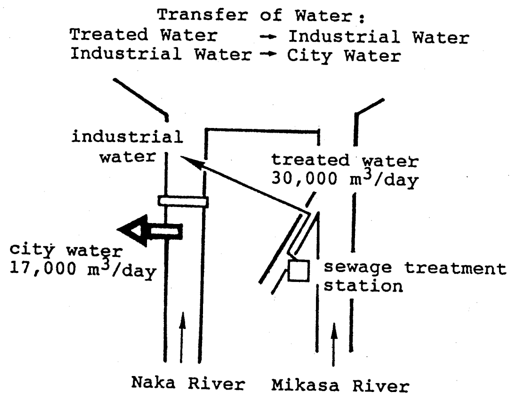


Fig. 9 Transfer of the treated water for industrial use and intake of the river water

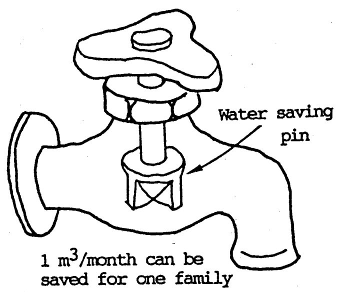


Fig. 10 Water saving pin

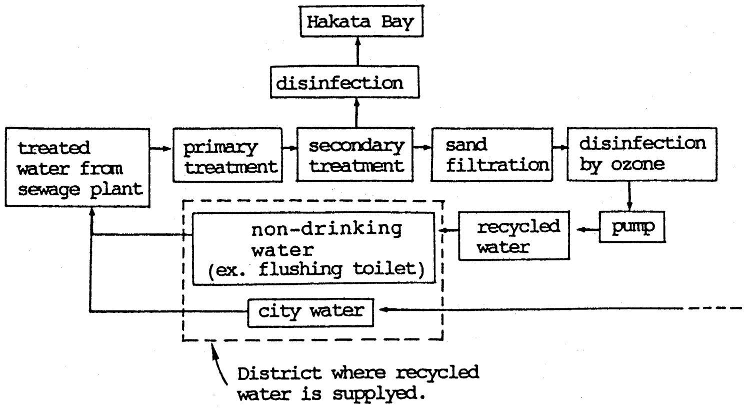


Fig. 11 Use of the recycled water

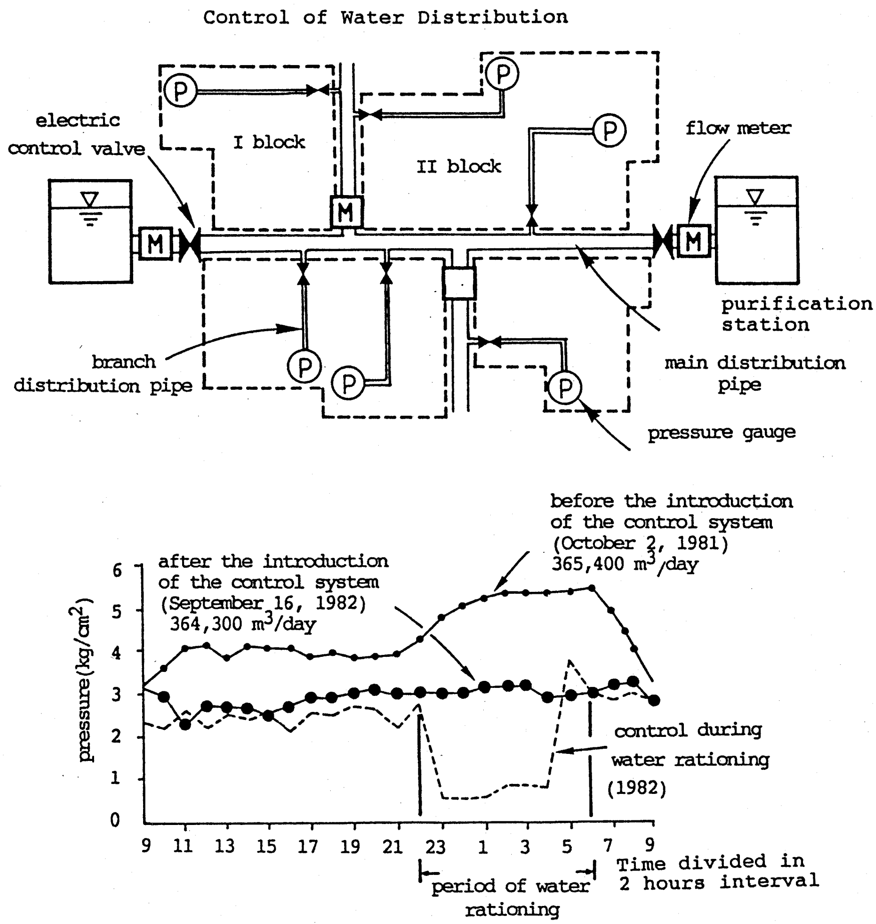


Fig. 12 Control of water distribution

caused a great deal of work and optimal pressure control was extremely difficult, an electric valve operation was introduced in 1981. This system not only controls the electric valves but also monitors the flow rate and pressure variations in the supplying area. The leakage of water from the pipelines can be reduced by controlling the pressure distribution as observed in the figure. In 1983, the water transfer from Chikugo River was started even though it was opposed by the people. The flow rate for the fishery and some environmental questions were disputed.

6 Conclusions

After the Fukuoka drought, the attitudes of the inhabitants towards the water resources problem may be established in their minds. They recognize that the use of water resources must be limited. Actually, the mean daily-individual water supply remains almost less than 320 l/day since the drought. On the other hand, it is our impression that cities seem to be growing and not taking into account the increasing size of the city and its relation to water resources limitation. Even though the people may be less likely to reject further water resources development, however, the projects which are neither dependent on dam constructions nor the water transfer from different regions should be considered as one of the key and indispensable answers for growing cities. Moreover, integrated water management is extremely necessary.

Acknowledgement

We would like to express our gratitude to the Agency of Water Supply of Fukuoka City for their valuable comments on this paper.

References

Akira Kawamura, Kenji Jinno, Toshihiko Ueda and Reynaldo R. Medina: Detection of abrupt change in water quality time series by the adaptive Kalman filter, Monitoring to Detect Change in Water Quality Series(Proceedings of the Budapest Symposium, July 1986), IAHS Publ. no. 157, 1987.

Akira Kawamura, Kenji Jinno, Toshihiko Ueda and Reynaldo R. Medina: Analysis of patterns in a precipitation time sequence by ordinary Kalman filter and adaptive Kalman filter, The Influence of Climate and Climatic Variability on the Hydrologic Regime and Water Resources(Proceedings of the Vancouver Symposium, August 1987), IAHS Publ. no. 168, pp.221-232, 1987.