(70) Decision Support System for the Water Resources Management
水資源管理のための意志決定支援システム

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水供給システムの信頼性は水資源の計画や運用にとってきわめて重要な課題であるが，想定外の厳しい渇水や水需要の急速な増加などによる水供給機能の低下は避けることができない．この場合，適切な水資源運用により渇水リスクを軽減することができると考えられる．本報では，いくつもの想定シナリオに対する水源管理・運用に必要な情報を提供する意志決定支援システム(DSS)について検討している．本システムは水管理データベースおよびいくつかの水計算モデルより構成され，これをパソコン上のユーザーフレンドリーなビジュアル表示を目的としたインターフェイスで構築している．そして福岡市を事例として検討している．

Abstract

This paper aims to develop a decision support system(DSS) for the water resources management applied to the existing water supply system of Fukuoka City. The DSS is a highly integrated model developed in order to assist decision makers by providing the information on hydrological characteristics of reservoirs and river conditions, the amount of water shortage, and the probable situation simulated under some drought scenarios. The developed DSS framework consists of a water modeling systems and a data base manager. The water modeling includes a rainfall-runoff analysis model for the catchment characterization and stream-flow forecasting, a water demand forecasting model and a water balance model by risk assessment being still under development.

1. Introduction

Within Fukuoka prefecture, Fukuoka city as well as the surrounding small communities are facing a threat of water shortage due to lack of water resources and water demand growth. Thus, construction of new reservoirs, desalinization using the reverse osmosis membrane and the further recycle of treated water are planned. However, the failure of the water supply system is unavoidable due to unexpected severe droughts with long-term return period and the delayed water resources development. Unless a fundamental strategy for the water resources planning and operation based on the ten-year return period is re-examined or a concept of risk management for drought in urbanized areas is considered, the robustness of water supply system may not be

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enhanced. Despite the effort for developing new water resources, the evaluation of the risk management of a decision making operation for the existing water supply system is becoming indispensable because drought is unavoidable.

The current DSS consists of two main modules, a data base manager and simulation models. The data base manager is based on standardized formats aiming for the integration of external software such as Microsoft Excel and/or Access. It permits to provide information about the water supply components and a multiple operations on the data base. The simulation models are the mathematical base of the DSS, it includes a rainfall-runoff analysis based on the application of the tank model, a domestic water demand simulation and a reservoir storage model based on multiresrvoir decision making by risk assessment.

2. Study area

Fukuoka City, a fast growing economic and cultural center in Kyushu, Western Japan, was struck by a severe drought in 1978 and 1994. The city area is 337 Km^2 and the population is 1.3 millions as of 1997. The hydrologic feature of Fukuoka city is characterized by a high seasonal variability of the precipitation. The annual average precipitation is about 1600 mm/year. Fukuoka City has a geographical disadvantage and water supply has to rely on small rivers and limited groundwater resources. As a result, the area is always exposed to potential drought,. In order to meet the increasing water demand, due to economic development and population increase, 7 reservoirs of various capacity have been constructed. Another water supply source was developed along the Chikugo river located outside the area limits in addition to some water take stations directly from some small rivers in Fukuoka City. Furthermore, the water supply system includes six water purification stations with a total capacity of about 704,800 m^3/day. More information and characteristics about the water supply components (reservoirs, water purification stations and water take stations from rivers) are provided through the data base window shown in Fig. 1.

3. User interface and data base manager

The present DSS involves the use of interactive computer graphics to provide an effective interface between the user and the data base management system (see Louks et al., 1985). The user interface is written in Microsoft Visual Basic and consists of tools and menus for data base management and mathematical models (Fig. 1). The data are accessible through multiple windows as shown in Fig. 2 to 5. At the present stage, the data base includes five-year (1991-1995) daily base data of rainfall, discharge from rivers, reservoir storage, reservoir release, water supply from water purification station, water take from the Chikugo and small surrounding rivers.

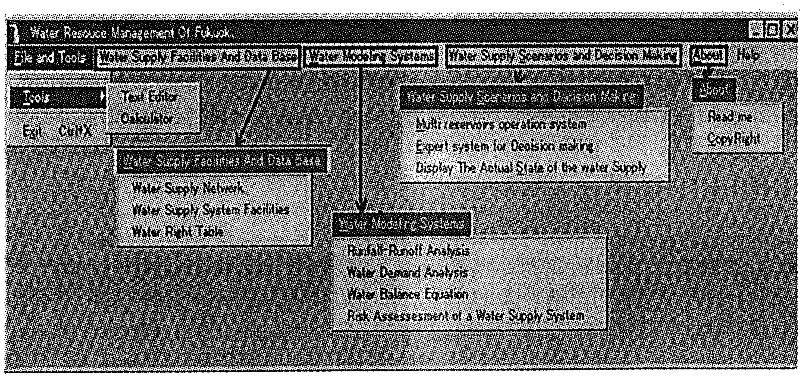

Fig.1 Framework of the current DSS.

4. Simulation models

The mathematical models contains rainfall-runoff analysis, domestic water demand estimation and a reservoir storage models, which are written in Fortran language. The user can involve one or more models from the DSS menu (see Fig.1).

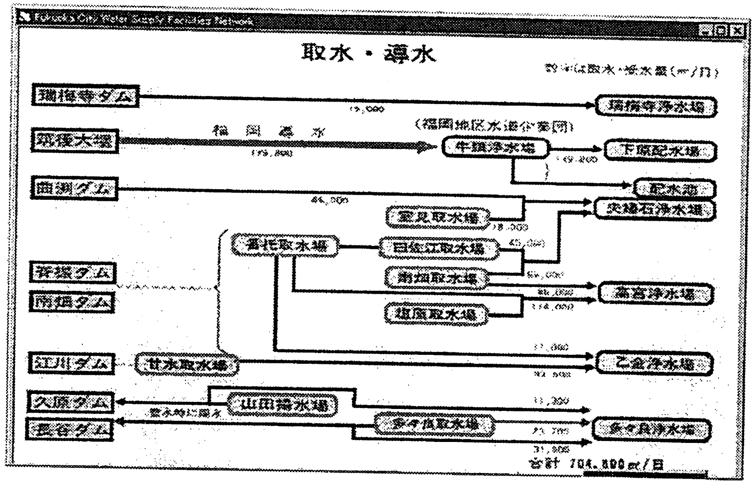

Fig. 2　Data base manager: Water supply system.

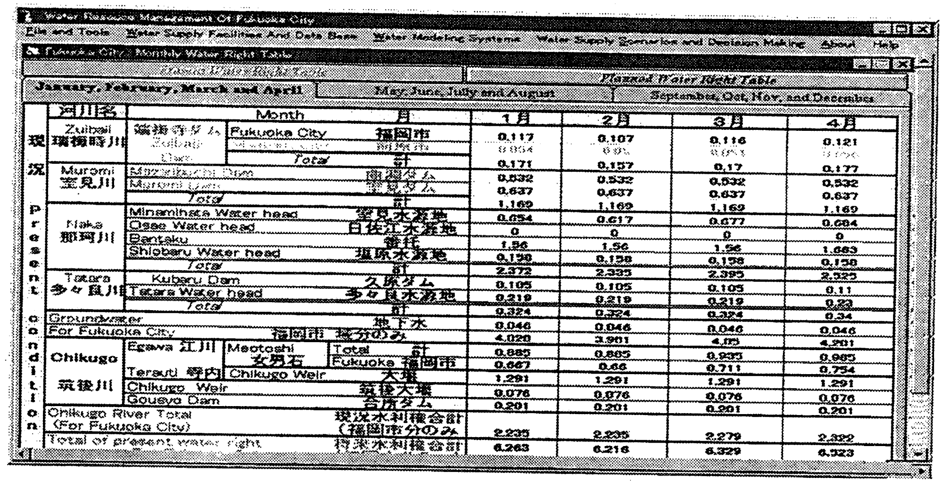

Fig. 3　Data base manager: Water right table of Fukuoka City.

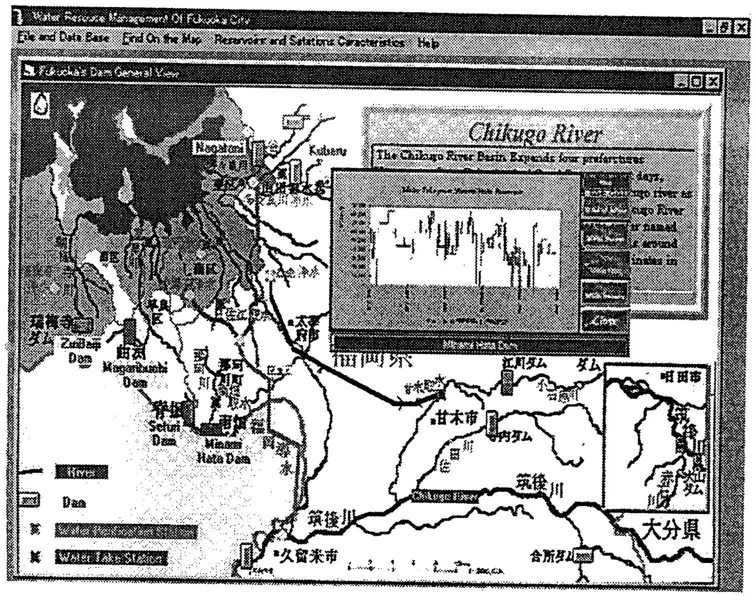

Fig. 4　Data base manager: Map of the Water supply system and hydrological data.

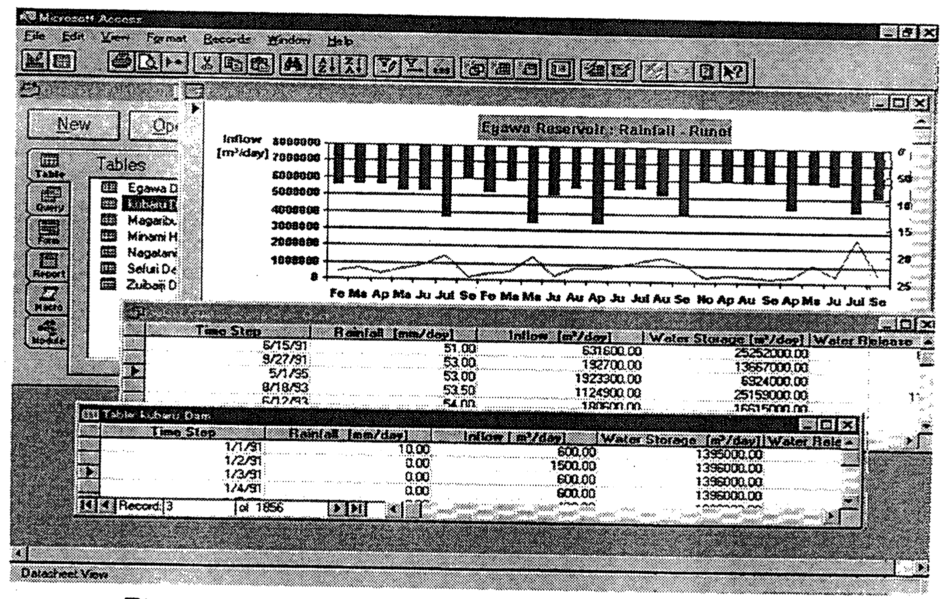

Fig. 5　Data base manager: data base in Microsoft Access.

4.1 Rainfall-runoff model

Tank model introduced by Sugawara (1961) is adopted for the hydrologic characterization of the catchments. The interface offer a quick and easy approach to select the appropriate data set for the calibration and validation of the model parameters (see Fig. 6). Currently the parameters are adjusted by trials-and-errors procedure as shown in Fig. 7. Therefore an automatic calibration method and an expert system for tank model are being under development. The potential user could select a multiple structures and configurations of a conceptual tank model, from a very simple one with 2 parameters to a very complicated one with 40 parameters. Furthermore, to assess the parameters reliability a number of statistical criteria are provided in addition to a graphic display. An application of the developed model to the characterization of Egawa reservoir is given in Fig. 8.

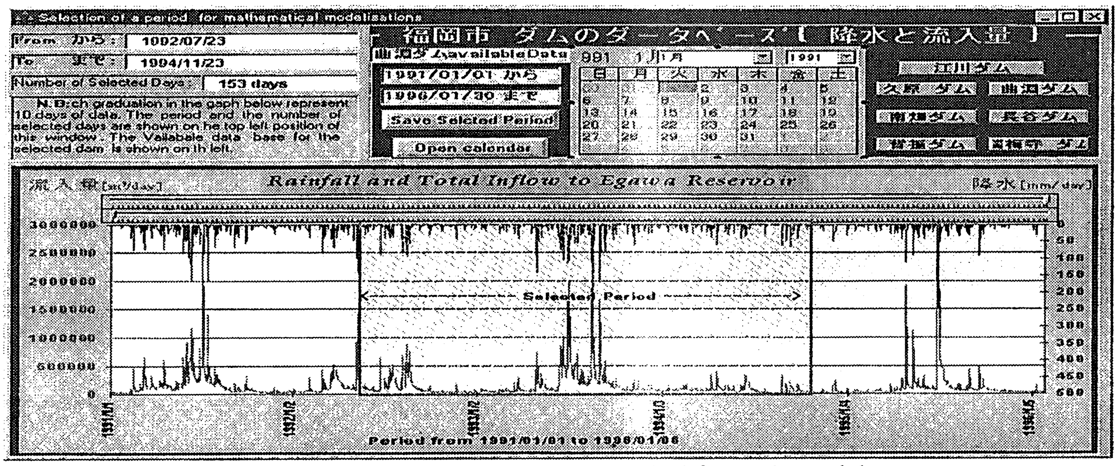

Fig. 6 Selection of a time period for tank model.

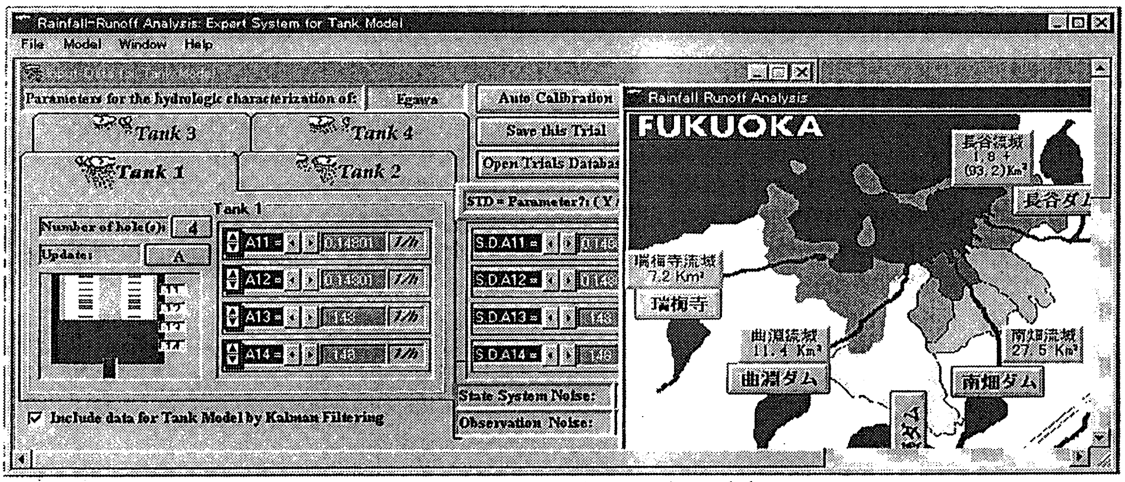

Fig. 7 Tank model interface and model parameters.

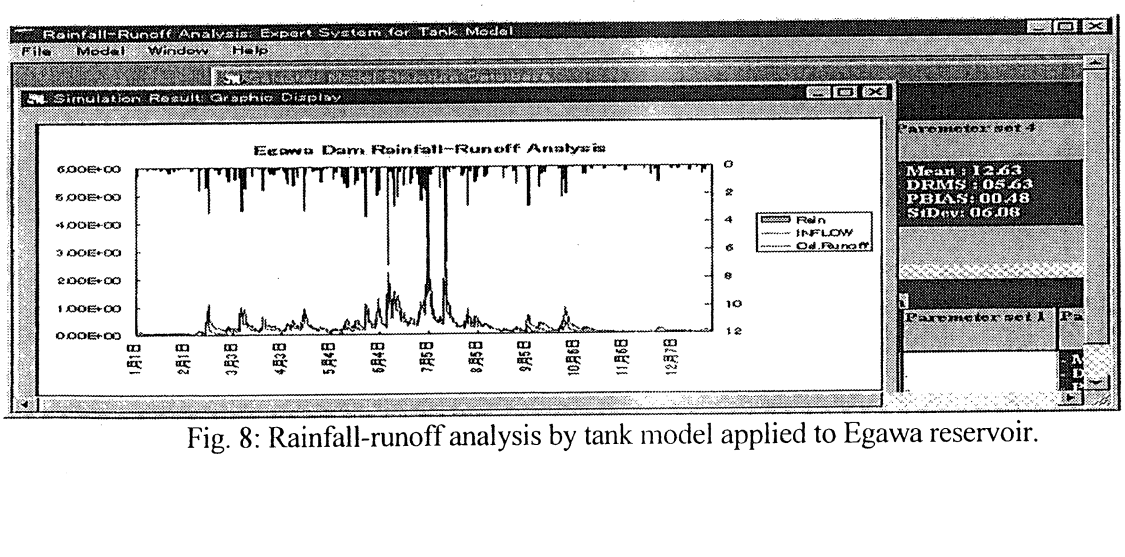

Fig. 8: Rainfall-runoff analysis by tank model applied to Egawa reservoir.

4.2 Water demand model

Domestic water demand model is involved as one of the target in the system. It uses a straightforward interface with several button to select an appropriate data base period to calibrate the model and update its parameters (see Fig. 9). The domestic water demand in a given time period is expressed as function of the daily water demand calculated by the intercept of linear trend at the beginning of the period, the monthly consumption coefficient, the daily consumption coefficient, the gradient of linear trend and the time period (Tajiri et al., 1997). The trend value expresses a general tendency in which the daily water demand is changing or developing. The domestic water demand equation is defined as:

$$Wd(t) = Gt * t + W_0 * Mc * Dc \qquad (1)$$

Where:

t : Elapsed time from the beginning of the period (day)
Wd : Domestic daily water demand (m^3/day)
Gt : Gradient of the trend (m^3/day/day)
W_0 : Intercept of linear trend at the beginning of the period (m^3/day)
Mc : Monthly coefficient (non-dimension)
Dc : Daily coefficient, i.e., weekly day or special day (non-dimension)

The parameters in Eq. 1 are evaluated from the historic data base of daily water suuply and did not include the climatic and hydrologic conditions. The application of the above model to Fukuoka city and the corresponding result are given in Fig. 9. During the drought period in 1994 the target daily water demand was not met due to the execution of water rationing.

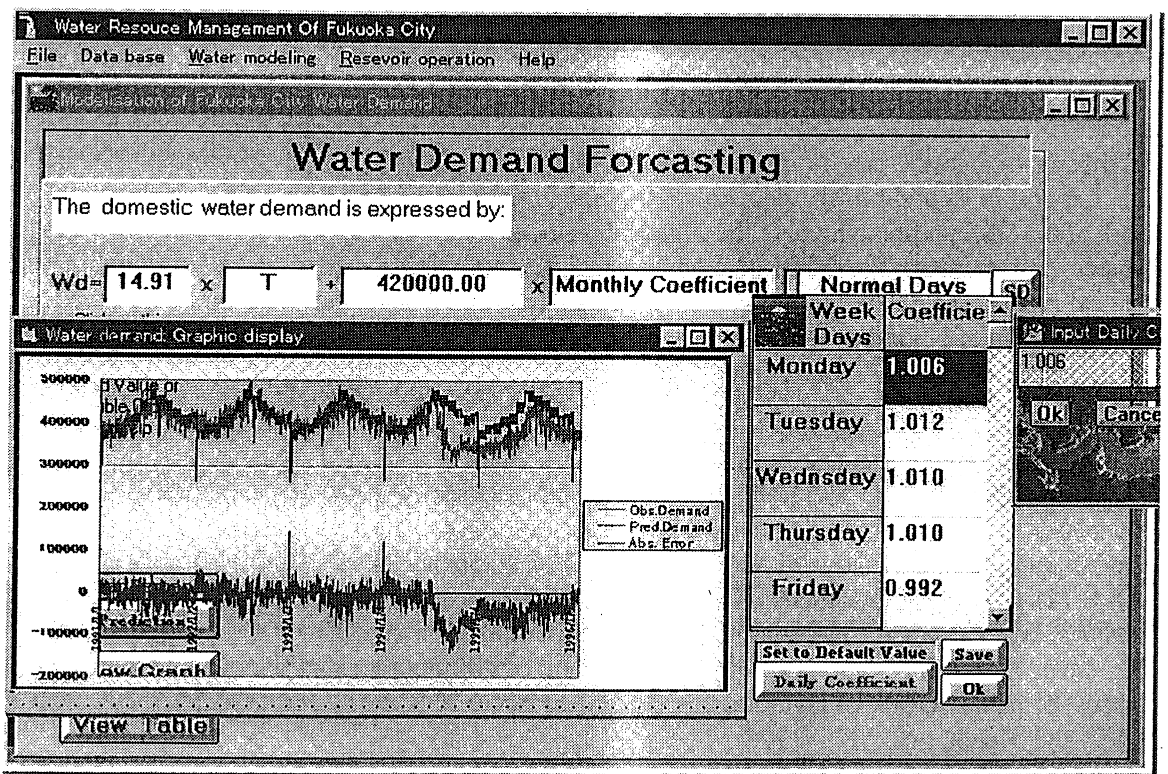

Fig. 9. Water Demand Framework model and simulation result

4.3 Reservoir storage model

The mathematical model used to simulate the variation of the water storage for each reservoir is based on the continuity equation given by:

$$\frac{dS}{dt} = I(t) - R(t) - L(t)$$

$$S_t = S_{t-1} + I_t - R_t$$

where t is the time period, S the water storage, I the inflow, R the release form the reservoir on the permitted water right presented in Fig. 3, and L loss from the reservoir. The constraints on storage and release variable are defined as:

$$S_{\min} \leq S_t \leq S_{\max}$$
$$R_{\min} \leq R_t \leq R_{\max}$$

where S_{min}, S_{max} are the minimum and maximum water storage, and R_{min}, R_{max} the minimum and maximum water release respectively. The release decision to be determined from each reservoir in order to meet the water demand and risk assessment analysis are currently under development.

5. Conclusion

Most of the published works in reservoir operation deal with simplified reservoir systems and have not been directly involved in the development of the computer system and thus are not entirely comfortable in using the models, particularly under the situation where modifications have to be made in the models to respond to changes encountered in the day to day operation. This work is an attempt to develop a DSS for reservoir operation, it is still in its preliminary step, however some important conclusions may be summarized. The basic framework of the DSS permit to involve the already developed model through a user friendly interface. The data base manger offers more flexibility in manipulating the data that a single software could provide. The mathematical models are easily updated and could be applied for a general purpose and not only to the existing water supply system of Fukuoka metropolitan area.

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