IMPLEMENTATION OF A DECISION SUPPORT SYSTEM FOR INTEGRATED RIVER BASIN WATER MANAGEMENT IN KOREA

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Abstract: This research presents a prototype development and implementation of Decision Support System (DSS) for integrated river basin water management for the flood control. The DSS consists of Relational Database Management System, Hydrologic Data Monitoring System, Spatial Analysis Module, Spatial and Temporal Analysis for Rainfall Event Tool, Flood Forecasting Module, Real-Time Operation of Multi Reservoir System, and Dialog Module with Graphical User Interface and Graphic Display Systems. The developed DSS provides an automated process of alternative evaluation and selection within a flexible, fully integrated, interactive, centered relational database management system in a user-friendly computer environment. The river basin decision-maker for the flood control should expect that she or he could manage the flood events more effectively by fully grasping the hydrologic situation throughout the basin.

Keywords: Decision Support System (DSS), Integrated River Basin Water Management (IRBWM), Flood Control, Database Management System, Real-Time Operation of Multi Reservoir System

1. INTRODUCTION

Since the International Conference on Water and Environment held in Dublin in 1992, the Integrated Water Resources Management (IWRM), the major resolution a series of international conferences on water have agreed upon, has been regarded as a solution many countries should adopt to deal with water issues with a view to efficiency, sustainability, and equity (Kim et al., 2004). In addition, tools for the basin-wide Integrated Water Resources Management (IWRM) for efficient and sustainable operation of the existing water resources facilities are urgently required (Shim et al., 2004). Historically throughout many of Korea water management problems have been compartmentalized for practical/administrative management reasons. A common split of the water management functions is flood prevention, water resources, environmental protection and landuse planning (HarmonIT, 2002).

One of the most important aspects of minimizing the impacts of floods is the operation of flood control systems. Most of the systems may include reservoirs for the flood control in a river basin in Korea. The real-time reservoir operation problem involves the operation of a reservoir system by making decision on releases, as information becomes available, with relatively short time intervals such as one hour. Real-time operations of multi reservoir systems involve various hydrologic, hydraulic, operational, technical, and institutional considerations, requiring an integrated river basin management framework. For efficient operation, a monitoring system is essential, which provides the reservoir operator with the flows and water levels at various points in the river system including upstream extremities, tributaries and the major river channel as well as reservoir levels, and precipitation data throughout the basin.

Grigg (1996) emphasized that there are many kinds of complexities and stresses that flood control should be seen as a part of integrated strategies of river basin management and not just as a single-purpose water project task. The development of integrated operational strategies for flood control and multi-purpose projects is crucial during real-time flood events and emergency conditions. This involves: a) creation of real-time hydro meteorological database management systems, b) calibration and implementation a real-time river forecast system, and c) configuration of a real-time optimal computer control system or integrated reservoir system operation (Labadie, 1990). A decision support system is an advisory system for management, usually computer-based, that utilizes a database, models and dialog system to provide decision makers with management information (Grigg, 1996). Computerization is an essential step in supporting the decision making process. Computing technologies not only organize and facilitate the processing of large amount of data, but they can also provide documentation of the process of selecting one alternative over all others. This research presents a comprehensive methodology focused on improving current approaches of flood forecasting and control systems using the enhanced technologies, neural network algorithm and multidimensional dynamic programming. The developed methodology has been embedded in a PC based Decision Support System (DSS) for the integrated river basin flood control. For implementing the prototype of DSS, several submodules and subsystems have been developed. The DSS consists of Relational Database Management System, Hydrologic Data Monitoring System, Spatial Analysis Module, Spatial and Temporal Analysis for Rainfall Event Tool, Flood Forecasting Module, Real-Time Operation of Multi Reservoir System, and Dialog Module with Graphical User Interface and Graphic Display Systems. The prototype system is intended to demonstrate the potential value of a DSS to water resources managers and engineers for operational flood management. The developed DSS provides an automated process of alternative evaluation and selection within a flexible, fully integrated, interactive, centered relational database management system in a user-friendly computer environment. The river basin decision-maker for the flood control should expect that he could manage the flood events more effectively by fully grasping the hydrologic situation throughout the basin.

2. DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR IWRM

2.1 Design of Structure

A Decision Support System is the integration of enhanced computer technologies, consisting of database management, a model base, a user dialog system and spatial analysis module subsystem. The functions of the database management subsystem are collecting, updating, processing, and managing the textual and geo-spatial data and distribute core of a DSS. Model base subsystem could solve the specific problems and generating useful information or alternatives for the overall decision making. Dialog subsystem can guide and help the user to solve specific problems through the querying, generating and providing the input/output data files for modules. Spatial analysis module subsystem has capabilities of processing, calculating, querying and generating the spatial relationship for geo-spatial data.

The schematic relationships between each component are represented in Figure 1. Each component is highly connected with others, centering on the database subsystem. Each subsystem was developed as an object using object-oriented programming techniques. The language, Visual Basic 5.0 for Window95, was used for the DSS development. For the model base, various programming languages and software were used such as FORTRAN, MATLAB, QuattroPro, and ACCESS. ArcView with Avenue was used as the development tool for spatial analysis module.

2.2 Operational Strategy of a DSS with Adaptive Control Process

It is practically impossible to perform the multi reservoir operation with large time step or over many stages in a short time period due to the computational time and memory requirements. Most mathematical and simulation techniques use the adaptive control process to overcome

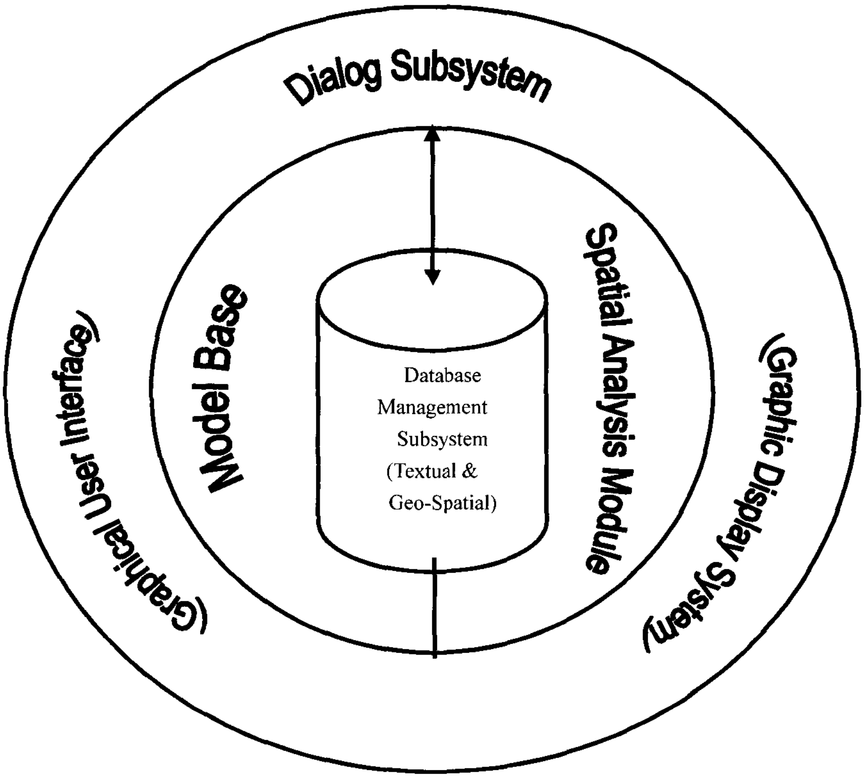

Figure 1. The schematic relationships between the each component of a Decision Support System

these limitations. The adaptive control process is one of the discretization techniques, which divides a time period into a series of small regions to enable the computation using a short time step. In this study, the developed software is executed for 24-hour time-steps then the time horizon is shifted by one hours and process repeated. The process is shown in Figure 2.

2.3 Development of the Database Management System

The real-time hydrologic data and attributes throughout the basin required for flood control are relatively large to implement in one database system. However, recently, there is enhanced and sophisticated database management software with built in tools of GUI, models and query systems. One of the more popular software for PC-based computer system is ACCESS for Windows from Microsoft Inc, which is a RDBMS. In this study, the rainfall data from 82 telemetry gages, water level data from 28 telemetry gages, and operational data of 7 reservoirs for 10 years (1987 – 1996) were collected, reformulated and then constructed as tables in a Han River Basin database system using ACCESS software. Original textural files from the Flood Control Office of the Han River Basin were extracted as raw data. The original formats of each data file for rainfall, water level of gages and operational data of reservoirs are represented from the Table 1. to Table 3.

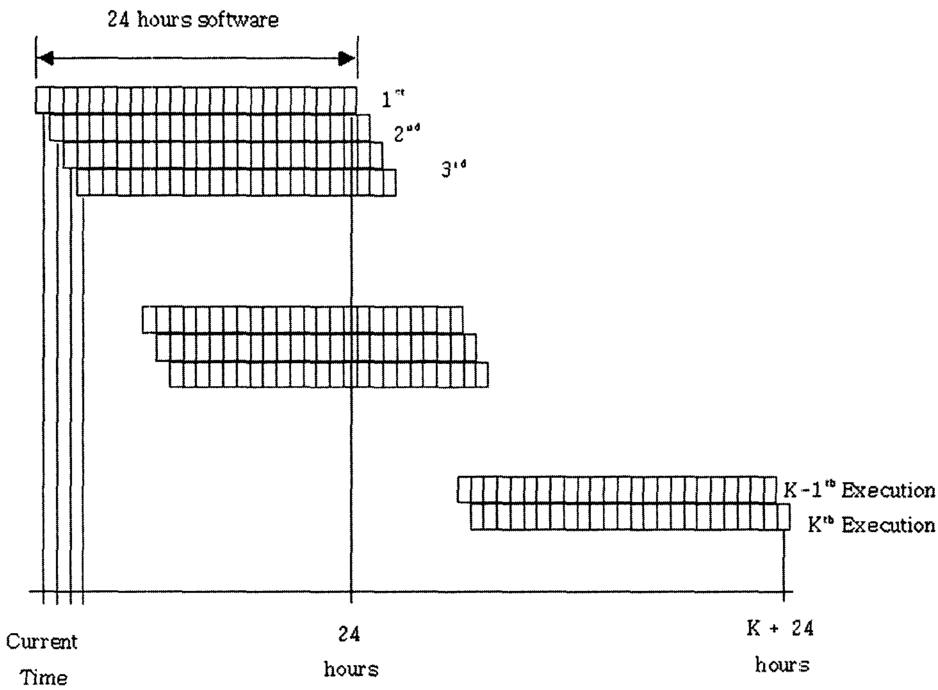

Figure 2. The Adaptive Control Process for real-time operation of a DSS.

Table1. Format of the original rainfall data for T/M gages

Field name	Date	ID of Gage	Value of T/M	Value of Modified	Rainfall	Accumulated Rainfall
Format	10	4	8	6	6	8
Example	1994091714	45	520	520	0	5

Table 2. Format of the original water level data for T/M gages

Field name	Date	ID of Gage	Value of T/M	Value of Modified	Water level
Format	10	4	7	5	7
Example	1990091717	18	00174	174	356

Table 3. Format of the operational data for reservoirs

Field name	Date	ID of Dam	Value of T/M	Value of Modified	Storage	Inf.	Rel.	No. of OG	Spill Rate
Format	10	4	7	7	7	7	7	5	5
Example	1987090415	6	09261	19261	2515	1576	1050	3	1000

To reformulate these original data files into suitable tables for the Han River basin database system programs were developed using Fortran programming and the QuattroPro for Windows spreadsheet. The structure of the rainfall, streamflow, and operational databases are indexed by each year of 10 years of data, as illustrated in Figure 3. The prefix of the table names represents the year of the database. The etymon of the table names represents the related reservoirs, rainfall and stream flow database as follows; FLD means rainfall, HH means stream flow, HWDM means Hwacheon Reservoir, SODM means Soyanggang Reservoir, CHDM means Chungju Reservoir, and PADM means Paldang Reservoir.

For attributes of the location maps of rainfall and stream flow gages, RAIN_ST and FLOW_ST tables were produced from information in various reports about the Han River Basin. These tables will be used in spatial analysis module directly. The original data files for rainfall, streamflow and operational data files were indexed by two fields, date and gage number (ID) in a single file for all 10 years. Therefore, seeking time for searching the 1-hour record of each gage or reservoir requires significant time. In the newly constructed database, the seeking time for searching the related record is reduced by segmenting the data files into individual tables as described in above and indexing a single field (i.e. date) for each table. Each table has a simple and meaningful structure as compared with the original data files. For the rainfall tables (xxxxFLD), the index field is DATE filed with ST1 to ST82 fields for gages, as illustrated in Figure 4.

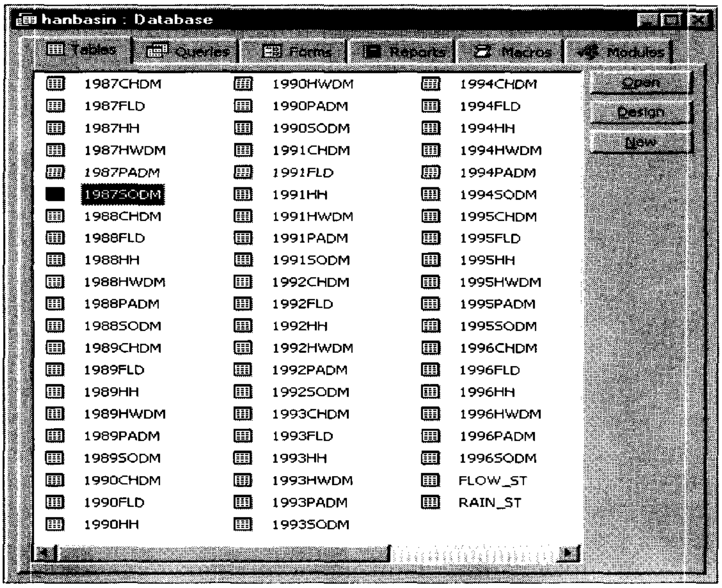

Figure 3. The tables of the hanbasin database system

Date	ST1	ST2	ST3	...	ST81	ST82
Time	record	record	Record	record	Record	record

Figure 4. The design of rainfall database tables

Date	STORAGE	INFLOW	RELEASE	SPILL	SPILL_RATE
Time	Record	record	record	Record	record

Figure 5. The design of operational database tables for reservoirs

Therefore, one can seek the rainfall records of all 82 gages or the rainfall record of just one gage depending on the user's query structure. Keeping the same logic, the tables (xxxxHH) for streamflow were constructed. However, the operational database tables for reservoirs have different fields compared with Figure 4 database tables described above. Since each reservoir has more fields, as shown in Figure 5, than the T/M gages, more segmenting works were involved.

The database tables of attributes for location maps use station_ID as the index field and other fields for various information. The structure of database table for the location maps is given in the Figure 6.

In the Figure 6 each field name has the following meanings: HAN_ID field is the record set, which is related to the field name in Figure 4 and Figure 5; ST_NAME is the gage name; BST_NAME is the Broadcasting Station name for each gage for the purpose of the flood warning system; LAT (DMS) is the latitude of each gage and LOG (DMS) is longitude of each gage. If more information is needed then it can be easily imported in to the database file. In addition, the spatial analysis module has also a lot of attribute tables with related themes. Spatial analysis tools in the spatial analysis module will generate the dynamic database tables for estimates of average rainfall and isohyets, which is shown in the Table 4. Finally, after forecasting the reservoir inflows and local inflows to the basin, the dynamic database tables will be updated as the results database table, shown in Table 5. Using this database table, the data files for the multireservoir operation model will be extracted.

ID	HAN_ID	ST_NAME	BST_NAME	LAT(DMS)	LOG(DMS)
ID	Record	record	record	Record	record

Figure 6. The design of database tables for Attributes of gages

Table 4. The dynamic database table for results of the spatial analysis

Fields	DATE	SB_1	SB_2	…	SB_30	NOTICE	ISOHYET
Format	Value (Int)	Value (Real)	Value (Real)	…	Value (Real)	Text String (500 Letter)	Image Name (File Path)
Example	9582123	2.5	3.0	…	10.0	Beginning Rainfall event	D:\Hanprojt\Products\ t082123.bmp

Table 5. The dynamic database table for results of the flood forecasting model

Fields	DATE	HWI	SOI	CHI	CCLI	UALI	CPLI	YJLI	PDLI	IDGLI
Format	Value (Int)	Value (CMS)	Value (CMS)	Value (CMS)	Value (CMS)	Value (CMS)	Value (CMS)	Value (CMS)	Value (CMS)	Value (CMS)

Table 6. The database table for results of the multireservoir operation model

Fields	DATE	HWSTO	HWREL	SOSTO	SOREL	CHSTO	CHREL
Format	Value (Int)	Value (MCM)	Value (CMS)	Value (MCM)	Value (CMS)	Value (MCM)	Value (CMS)

2.4 Development of the Graphical User Interface

2.4.1 Overall design of GUI

There are several philosophies for designing effective Graphical User Interfaces (GUI). One of the cornerstones of the good user interface design is consistency. The definition of consistency is the ability of the user to predict what the software is going to do in a given situation, based on past experience with the product. The programmer should provide clear and obvious paths for the user to accomplish desired tasks. Considering these concepts, the graphical user interfaces were designed for the flood forecasting and multireservoir operation modules and hydrologic data monitoring system as well as the customized spatial analysis module. The overall design of the graphical user interface and graphic display system is shown in Figure 7. The GUI consists of Menus and Toolbar Controls where the user can invoke the each module by clicking either the related menu or the button on the toolbar. This will invoke the GUI for each module.

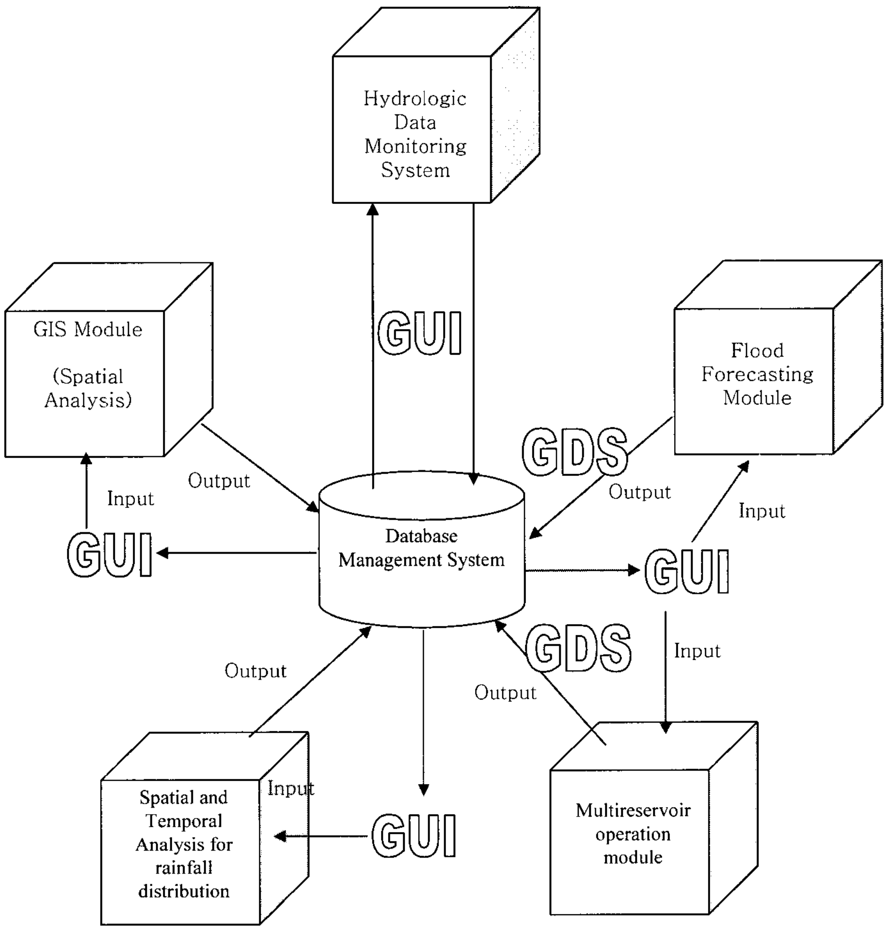

Figure 7. The overall design of the GUI/GDS for subsystems

2.4.2 GUI/GDS for the Hydrologic Data Monitoring System

For providing the hydrologic information of the preceding 24 hours to the decision-maker, a Hydrologic Data Monitoring System was developed. The main GUI of the system consists of the Picture Control for showing entire Han River Basin, the List Box Controls of rainfall and water level gages, Text Box Controls for longitude and latitude and the Text Frame Control for map extension (Figure 8).

The major function for the Hydrologic Data Monitoring System is to query the information from the developed database system described in Section 2.3. To query the information, first, the user has to click a circle or rectangular shape on the Picture Control. This causes highlighting of the related name of gages in the List Box Control. The GUI displays the hyetograph or hydrograph by double clicking the highlighted name of gages.

Figure 9 shows the information for a rainfall gage, its related hyetograph and distribution of rainfall intensity for the preceding 24 hours. Figure 10 displays the information for a water level gage and its related hydrograph. Using the Hydrologic Data Monitoring System, the user can grasp immediately the hydrologic conditions throughout the basin. In addition, the user can extract a table for current rainfall data for 82 gages, which can be used in the spatial analysis module to create isohyets.

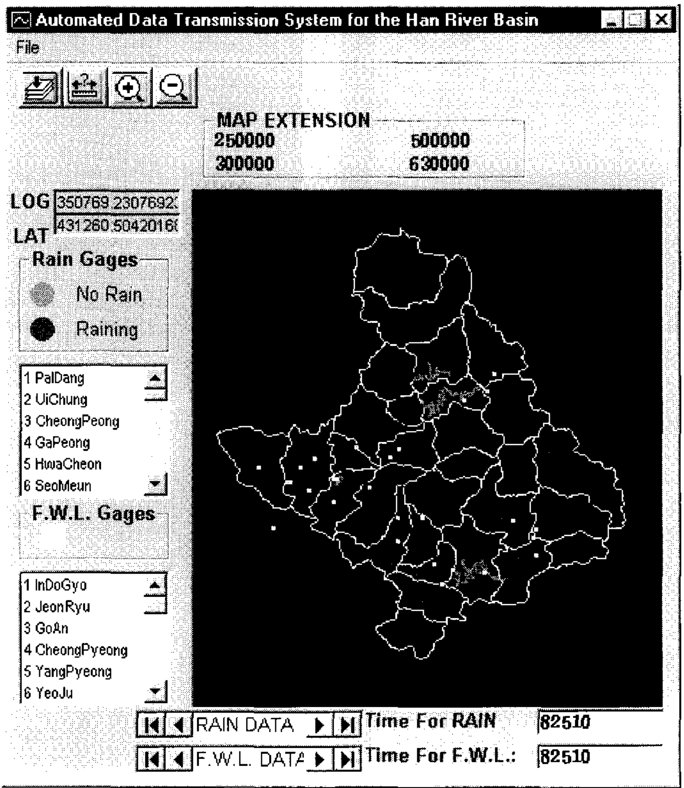

Figure 8. The Main GUI for the Hydrologic Data Monitoring System

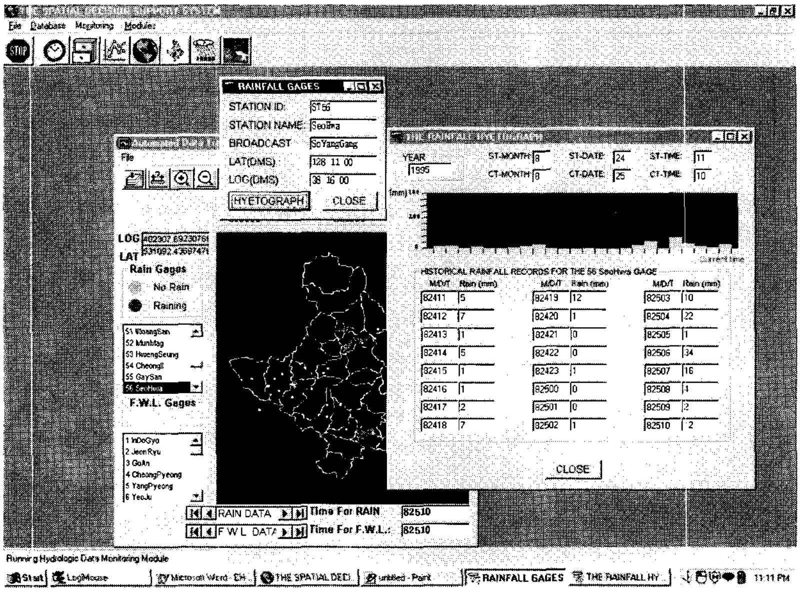

Figure 9. The GDS for Rainfall Gages and its Hyetograph

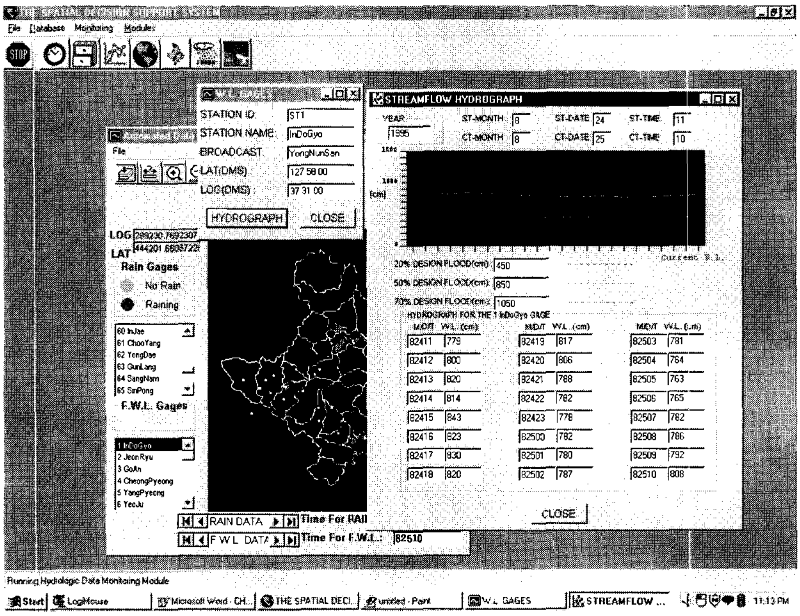

Figure 10. The GDS for Water Level Gages and their Hydrograph

2.4.3 Development of GUI for the spatial analysis module

For ease in performing the spatial analysis, a GUI for the spatial analysis module was developed using Avenue in ArcView. First, the user has to define a base map and analysis property, such as map extension and resolution of the created isohyets. Then, the module generates an isohyet image (GRID data format in ArcView) and a table for areal estimates of rainfall by using current rainfall data from 82 gages. Finally, the results of isohyet and table could be restored in the Dynamic Database Table. The design of GUI for the spatial analysis module is shown in Figure 11.

2.4.4 Development of the Spatial and Temporal Analysis for Rainfall Tool

The spatial and temporal rainfall distribution throughout the basin is important to understand the rainfall characteristics and its effects. In this study, rainfall data were analyzed with topographic coverage of Han River basin. The spatial and temporal analysis for the rainfall tool gives to the user or decision-maker considerable information about the results of the analysis. In Figure 12, the isohyet view screen located in the left top of the tool displays the isohyets for every time period to display rainfall conditions throughout the basin. The legend is located in the left of the isohyet view screen. There are ten frames to display numeric values of mean rainfall for each subbasin related with the catchment area of the forecasting point in the rainfall-runoff module. There are two kinds of text boxes with numeric values for each frame. The gray background textbox and the colored background textbox display the current and 24 hours accumulated rainfall of the subbasin, respectively. The background color of the textbox for accumulated rainfall changes depending on its magnitude. For example, green refers to less than 80 mm, yellow refers to greater than 80 mm and less than 150 mm, and red refers to greater than 150 mm. The user can immediately recognize the rainfall conditions using this coloring of the textbox.

This schema might be used for a flood early warning system. Using the data control, which is located in middle on the left of the tool, the user can explore the isohyets as well as view numeric values up to the current time period.

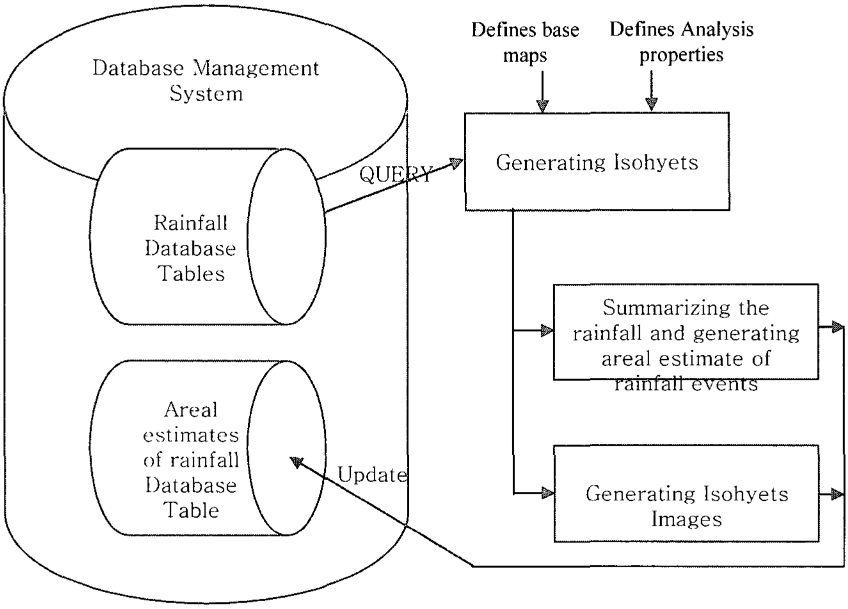

Figure 11. The design of GUI for the spatial analysis module

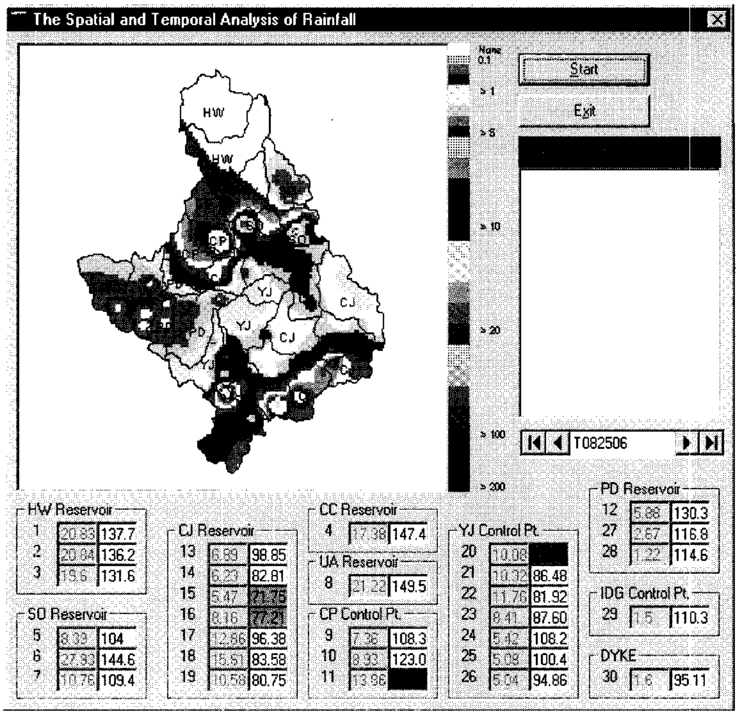

Figure 12. The overall design of the spatial and temporal analysis of rainfall tool

In addition, the meteorologist could provide notice or advice to the decision maker in order that they can be more reliable and effective in decision-making for the flood control. For this purpose, the large textbox was provided, which is located in middle on the left of the tool. Finally, two command buttons were provided. The start command button is for the animation or temporal analysis of the rainfall distribution. If the user pushes this button, the isohyets from beginning of rainfall events up to the current time will be automatically displayed both with images and numeric values. In addition, after pushing this button, the button's caption will change to "stop" to be used to stop the temporal analysis rainfall events. The "Exit" command control button is for returning to the main graphical user interface.

2.4.5 The Development of a GUI/GDS for the Flood Forecasting Module

The GUI for the flood forecasting module consists of a GUI for training the ANN models and a GUI for flood forecasting purposes. The overall design of GUI and Graphic Display System (GDS) for flood forecasting is shown in Figure 13. The GUI helps the user to easily create input data files for the models, both for the training and forecasting submodules, by automatically extracting the data from the database.

After training all models to the user's satisfaction, the user can forecast the inflows and local inflows. At this moment, the GUI also automatically extracts necessary data files from the database. After executing the flood forecasting models, the user can review the results by using the Graphic Display System (GDS), shown in Figure 14.

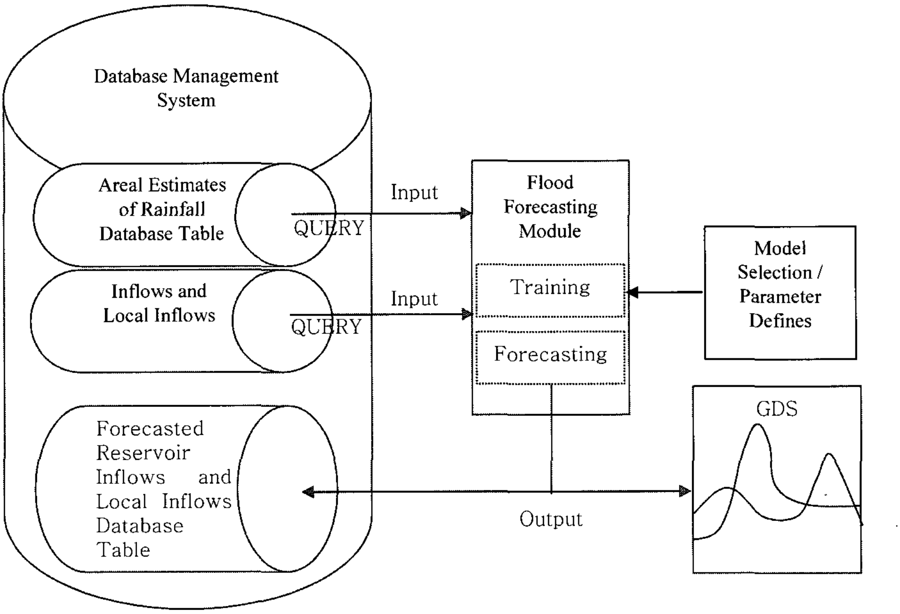

Figure 13. The design of GUI/GDS for the flood forecasting module

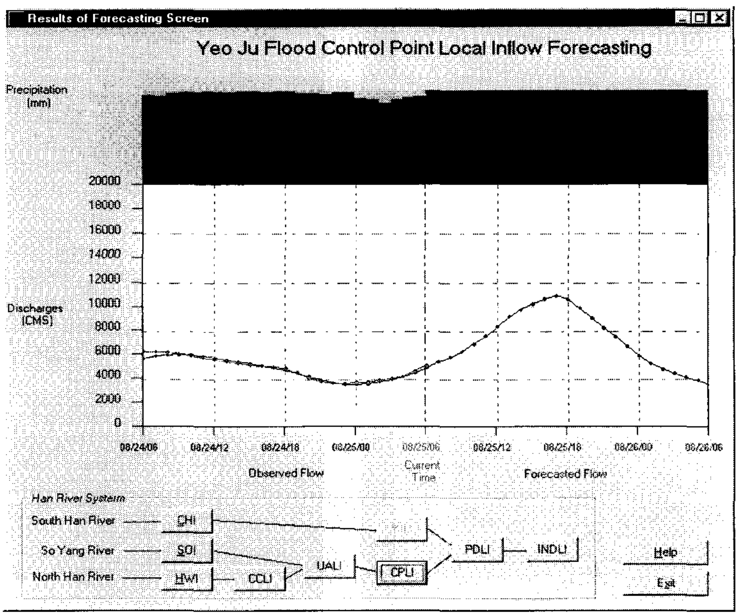

Figure 14. The GDS for the Flood Forecasting Module

The GDS displays valuable information. First, it displays the 24 hour previous average rainfall data throughout the related catchment area on the upper portion of screen. Second, the GDS displays the comparison between the observed preceding the 24 hours and the forecasted flows on the left side of the screen. Finally, the GDS displays 24 hours forecasts for inflows or local inflows. Combining this information and user's own judgement, he should evaluate the volume and peak flow for the next 24 hour period. There is a Frame Control captioned with Han River System on the lower portion of the screen shown in Figure 15. It consists of nine Command Controls with captions. The user can explore the result of a model by clicking a Command Control Button.

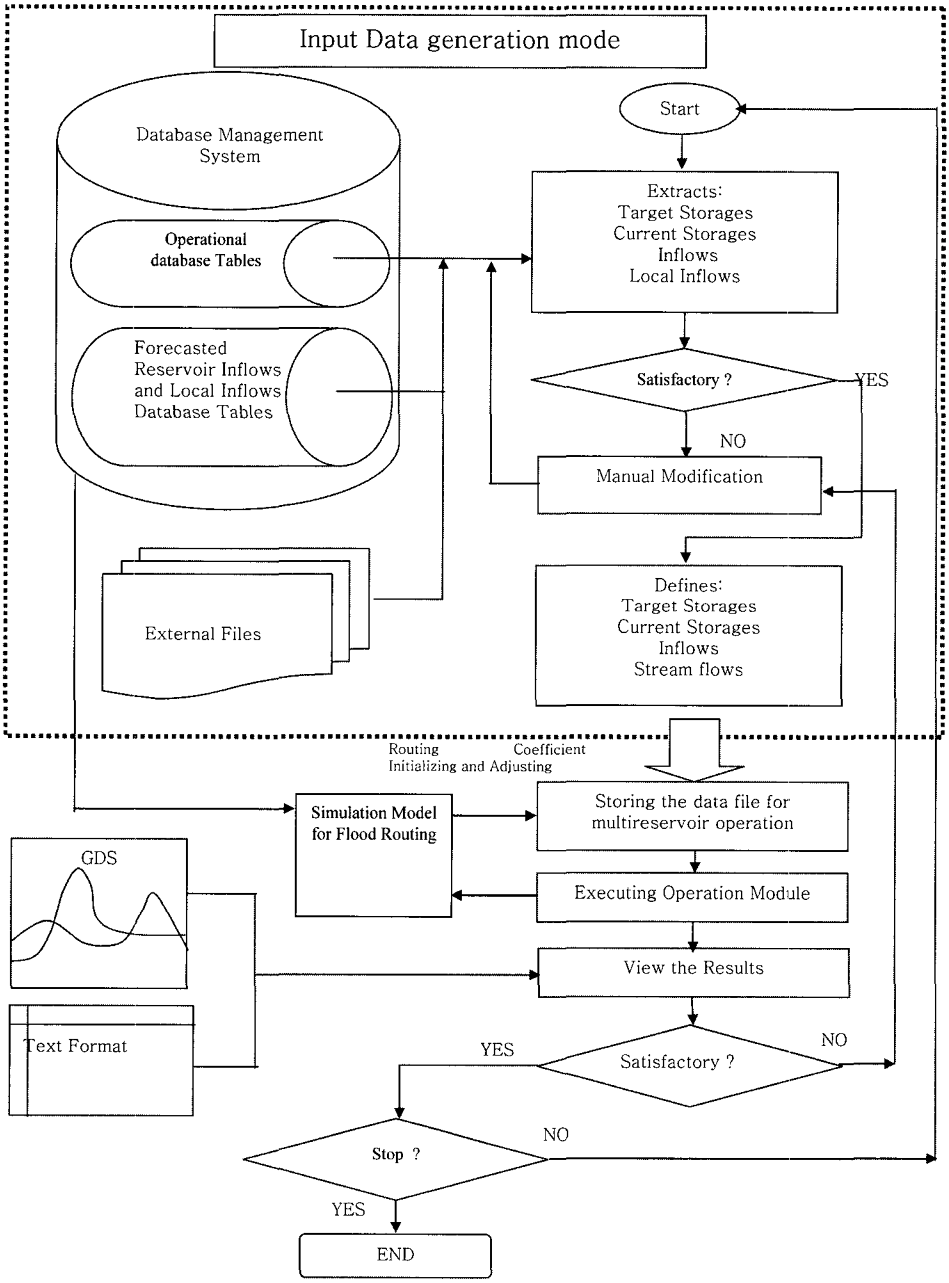

Figure 15. The design of the GUI/GDS for the multireservoir operation module

2.4.6 Development of a GUI/GDS for the Multireservoir Operation Module

The GUI/GDS for the multireservoir operation module consists of four different parts: 1) creating input data files, 2) executing the HRBSDP, 3) executing the ROUT program and comparing the sum of squared errors between the previous and current routing coefficients and 4) the GDS for the results of the operation module. The overall design of the GUI/GDS for the multireservoir operation module is shown in Figure 15.

The main GUI for the multireservoir operation module consists of six captioned Command Controls. The user can go to the subordinate GUI by clicking a Command Control. For instant, if the user clicks the CREAT INPUT FILE Command Control, it will display the subordinate GUI for the input data file creation mode. The subordinate GUI for the input data file creation mode is designed to generating input parameters for the HRBS.ADD file. This file is required by the HRBSDP to run using four different input modes. Each input mode is initialized with default values developed by the author. The user can modify these values manually by using the TEXT INPUT BOXES. Each input mode has a RESET Command Control to bring up the default values and an OK Command Control to store the specified values into memory. After all the input parameters are defined, the user can extract input data files by clicking the EXIT Command Control (all GUI are shown in Figure 16).

Now, the user can execute the HRBSDP program by clicking the Operation Command Control shown in Figure 16. Figure 17 shows an example display of the HRBSDP running. After executing the HRBSDP, the user must click the Compare Command Control to execute the ROUT program and calculate the sum of squared errors of the routing coefficients.

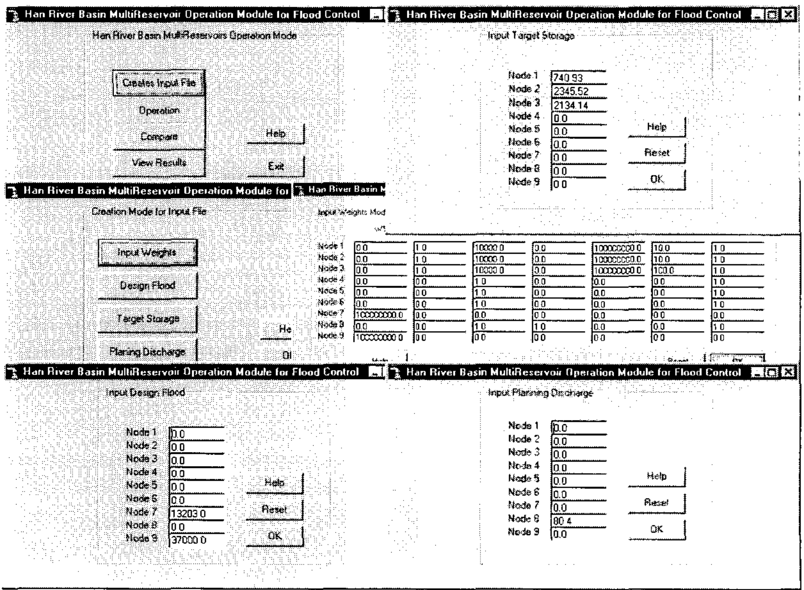

Figure 16. The GUI/GDS for the multireservoir operation module

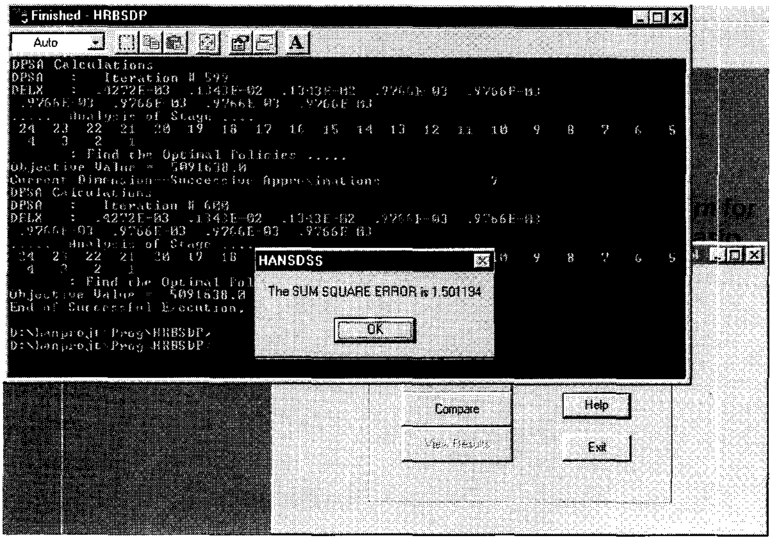

Figure 17. The HRBSDP program execution and the Message Box for Comparison of Routing Coefficients

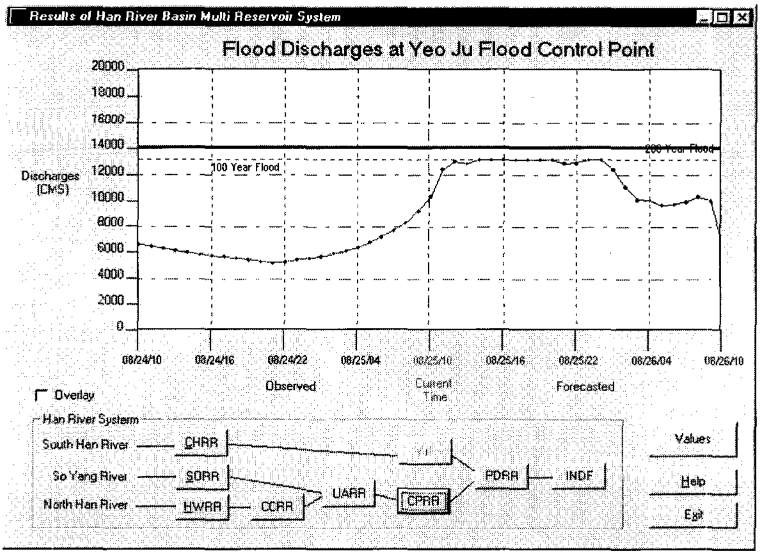

Figure 18. The GDS for Multireservoir Operation Module

The result of clicking the Compare Command Control popup message box with the sum of squared errors between the previous and current routing coefficients, shown in Figure 17. A Graphic Display System was developed for displaying the results of the HRBSDP, shown in Figure 18. The previous 24 hour observed operational data and the 24 hours forecasted operational data are plotted on the left and right side of the screen, respectively as shown in Figure 18. In addition, the user can also see the result files by clicking the Values Command

Control on bottom right of the screen as shown in the Figure 18.

The result file shows the customized output file for the HRBSDP, which was shown in Figure 19 as an example.

3. IMPLEMENTATION OF DSS FOR IWRM

The annual average precipitation of Han River Basin is 1294 mm, which is concentrated in June to September around 65%. The regional distribution of the rainfall is concentrated in downstream area that is located between Chuncheon and Yeoju. Especially, the annual average precipitation of upstream of Yeoju is 800 to 900 mm. The major causes of the flood in Han River Basin are typhoon and depression torrential storms. The typical cases of the typhoon storm are the 1925, 1936, and 1940 flood events. However, most of the flood events are due to the depression torrential storm. The representative examples of the depression torrential storm are the 1960, 1965, 1972, 1984 and 1990 flood events, which had been occurred continuously for several days. The sever case of the flood event is due to the both of the typhoon and depression torrential storms simultaneously. The '1995 flood event is the examples of this sever case.

The implementation of the developed spatial decision support system for the integrated flood control in Han River Basin, the '1995 flood event was selected. The characteristics of the 1995 flood events are follows as: due to typhoon and depression torrential storms simultaneously, began in downstream area of the basin near the West Sea and moving to the catchment area of the reservoirs, upstream of the basin, the first torrential precipitation was concentrated through the 17th to 21st of August, which is 179 mm throughout the basin, the second torrential precipitation was concentrated through the 22nd to 27th of August, which is 375 mm throughout the basin and the flood events was occurring after sever droughts.

To validate the developed system, the rainfall data of 82 gages were extracted during Aug. 22nd

HRBMAS RESULTS

MENU

So Yang Gang Reservoir Operation Results

No of Operation Time 5

STAGE	ST-STO(MCM)	ED-STO(MCM)	INFLOW(CMS)	RELEASE(CMS)
1	2508.680	2520.600	4481.042	1170.440
2	2520.600	2529.470	4505.532	2039.890
3	2529.470	2539.060	4722.654	2060.060
4	2539.060	2549.290	4901.435	2058.830
5	2549.290	2559.520	4901.000	2060.060
6	2559.520	2569.180	4735.088	2050.890
7	2569.180	2578.210	4569.750	2060.670
8	2578.210	2585.970	4229.472	2074.110
9	2585.970	2593.390	4127.769	2066.170
10	2593.390	2600.450	4037.170	2075.330
11	2600.450	2607.090	3903.910	2060.670
12	2607.090	2613.160	3758.121	2071.060
13	2613.160	2618.810	3639.977	2069.830
14	2618.810	2623.670	3439.442	2089.390
15	2623.670	2628.030	3299.512	2089.390
16	2628.030	2632.240	3255.613	2083.890
17	2632.240	2635.880	3098.842	2088.780
18	2635.880	2638.180	2720.975	2082.670
19	2638.180	2640.010	2589.038	2078.390
20	2640.010	2642.570	2799.530	2088.780
21	2642.570	2644.860	2724.207	2089.390
22	2644.860	2647.110	2710.089	2083.280
23	2647.110	2647.870	2306.860	2096.720
24	2647.870	2640.550	61.671	2094.280

Figure 19. The Result File for the Multireservoir Operation Module

to 27th of August in 1995 from RDBMS. Based on extracted rainfall data, the spatial analysis was performed to create the isohyet result in generating the dynamic database file. The Flood forecasting module involved in the inflow and local inflow forecasting dynamically. An example of flood forecasting module is represented in Figure 20.

24 precedence average rainfall, training performance, forecasting results are represented simultaneously in Fig. 20.

The Real-Time Multireservoir operation module can find optimal strategies for release without violating the downstream capacities. An example of Yeoju flood control point is represented in Figure 21.

In Figure 21, the observed operational data shows that the flood flow violated its capacity in both 100year and 200year floods. However, the result of the real-time multireservoir operation module did not violate 100year flood.

4. CONCLUSION

During the real-time flood events, the operation of water surface system is important and crucial to minimize the impacts of flood. For the ease use the water surface system for the flood control, PC-based Decision Support System was developed. For developing a Relational Database Management System (RDBMS), first, original textural files from the Flood Control Office of the Han River Basin were extracted as raw data. These textural files consisted of the rainfall data of 82 telemetry gages, water level data of 28 telemetry gages and operational data of 7 reservoirs for 10 years (1987 – 1996). The original data files for rainfall, stream flow and operational data files were indexed by two fields, date and gage number (ID) in a single file for all 10 years.

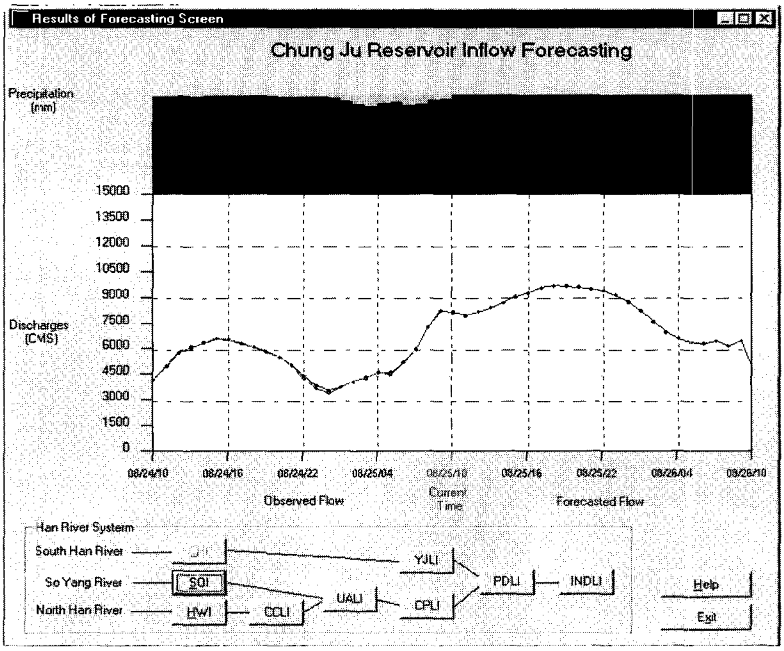

Figure 20. The GDS for ChungJu Reservoir Inflow Forecasting Result

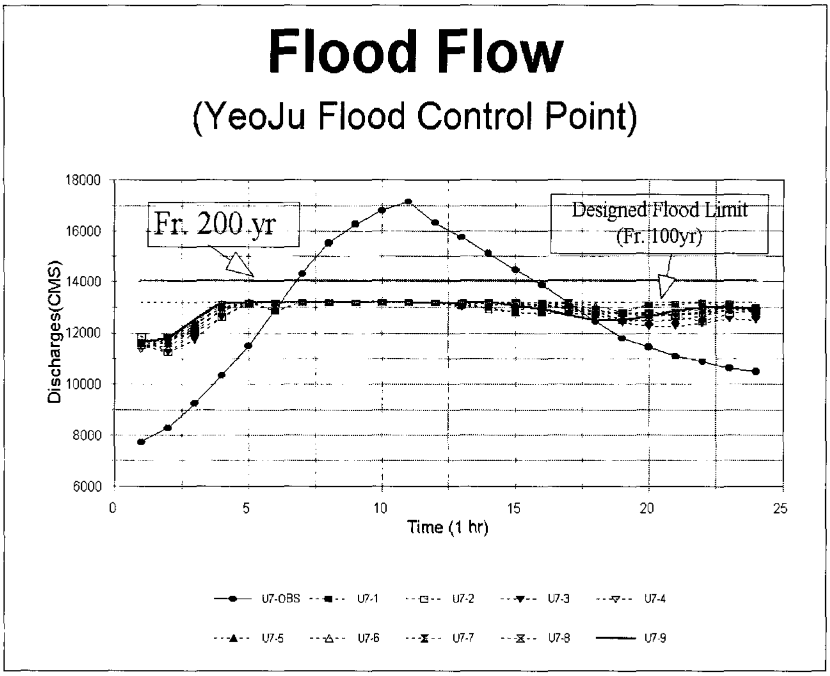

Figure 21. Comparison of Observed Operational Data with Simulated One

Therefore, seeking time for searching the 1-hour record of each gage or reservoir requires significant time. In the newly constructed database, the seeking time for searching the related record was reduced by segmenting the data files into the each table and indexing just a single field (i.e. date), for each table. To reformulate the data file into suited tables for the Han River Basin database system simple FORTRAN programs and the QuattroPro for Windows spreadsheet were used. The developed RDBMS serves the as center of the DSS by updating the real-time hydrologic data throughout the basin and generating the necessary data files for various modules in the system.

For providing the hydrologic information of the preceding 24 hour period to the decision-maker, a Hydrologic Data Monitoring System was developed with a Graphical User Interface (GUI). A spatial and temporal analysis rainfall tool has been developed to give the user or decision-maker a lot of information about the results of the spatial analysis. For creating input files, execution, and displaying the results of various modules, Graphical User Interfaces (GUI) and Graphical Display System (GDS) have been developed and integrated to a Decision Support System.

Finally, 1995 flood event was used as a case study to demonstrate the developed the integrated river basin flood control for Han River Basin in Korea. Utilizing this flood event, spatial analysis, flood forecasting and real-time operation of the multireservoir system were evaluated. The prototype system is intended to demonstrate the potential value of a DSS to the water resources managers and engineers for the operational flood management. The DSS provides an automated process of alternative evaluation and selection within a flexible, fully integrated, interactive, user-friendly computer environment. The river basin decision-maker for the flood control should expect that he could manage the flood events effectively grasping the hydrologic situation throughout the basin.

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