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ARCHITECTURE PLANS FOR A FLASH FLOOD FORECASTING SYSTEM

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1. INTRODUCTION

Annual flood losses during the 1970's averaged nearly 200 lives and $2 billion in property damage (Barrett, 1983). Loss of life is primarily caused by flash floods, loosely defined as rapidly occurring floods that typically crest in less than 12 hours. Flood losses can be reduced significantly by forecasts having reliable lead times and accuracy (Changnon et al, 1983; Jettmar et al., 1979; Krzysztofowicz et al., 1979; Day, 1970). The National Weather Service (NWS) has been mandated by the Organic Act of 1877 to provide flood warnings nationwide.

Problems with flash-flood forecasting within the NWS have been caused by limited computer resources at local field offices and inadequate rainfall data for small areas and short time periods. However, the modernization plans of the NWS call for maximizing the use of automated data collection systems and implementation of an Advanced Weather Interactive Processing System (AWIPS) in each office (Schmidt, 1986). Thus, plans have been initiated to develop a system for flash-flood forecasting that takes advantage of advances in data acquisition, information processing, and modeling techniques. This system is referred to as the Forecasting and Local Analysis System for Hydrometeorology (FLASH).

Formulating a system architecture plan has been identified as an essential step in the development of FLASH and improved flash-flood services (National Weather Service, 1984). It is envisioned that FLASH will be developed by integrating existing systems and techniques with several new ones. A design plan is needed to allow coordinated development effort and logical use of current and future systems.

The objective of this paper is to describe a proposed conceptual design of FLASH. Several important system considerations are addressed, namely, the goals, operating environment, individual components, and interaction of the components (McCuen, 1985). It should be recognized that FLASH is in an evolutionary review process and the final design may be different from the one described here.

2. FLASH GOALS

The prime function of FLASH is to produce timely and accurate flash-flood warnings for public dissemination. Accuracy will be achieved by utilizing high resolution rainfall data and advanced hydrometeorologic analysis techniques. Also, error estimates will be produced with each forecast. Early warnings will be achieved by using short term rainfall forecasts. Warnings will also be made timely by the efficiency and automation of the communications, data collection, and analysis. Further, warnings will be made more effective through use of an information system to add more site-specific information. Carter and Clark (1983) indicate that the credibility and reliability of a warning increase as more site specific forecasts, related to an individual's risk, are produced.

3. OPERATING ENVIRONMENT

FLASH will be used nationwide by meteorologists at the local Warning and Forecast Offices of the NWS. It is intended to function as a subsystem within AWIPS and share a data base with other subsystems. The shared data base, along with its combined rainfall analysis and hydrologic forecasting, make FLASH a truly integrated hydrometeorological system, which is considered a most effective approach (Hall, 1981).

FLASH will operate in real time, i.e., data will be received at intervals ranging from 15 minutes to several hours and forecasts will be output for streams with response times of 1 to 12 hours. The environment of a short-fused flash flood provides little time to a forecaster for data collection and analysis. Thus, these functions will be automated. However, the flexibility of FLASH will provide detailed informative output allowing the forecaster to interact with the system by displaying or changing any data used in the analysis.

4. COMPONENTS

Components and their interaction are discussed according to three categories common to any system definition: input, processes, and output (McCuen, 1985). The components are considered independent, i.e., each component, though related to the others, knows only its inputs and outputs but not their origins and destinations (Keller, 1983). A hierarchical, top-down approach is taken which starts at a high level and then defines each component at successively finer levels of detail. Components were conceptualized by formulating the functions necessary for FLASH and assessing the feasibility of performing the functions by means of various current and planned technologies.

4.1 Input

The primary input will be real-time rainfall data and river stage data received at irregular times and high volumes. This will include gaged rainfall observations and rainfall estimates obtained from satellites (Moses, 1985) and from high resolution (e.g., 2 km x 2 km grid) NEXRAD radar (Ahnert et al., 1983). Data will be acquired in short-time scales, e.g., one hour or less, preferably every 15 minutes. All real-time data will be screened by an automated quality control process such as that described by Krajewski (1986).

Gaged observations will be obtained primarily from automated gages and data collection systems, such as those described by Barrett (1983). The availability and formats of these data vary greatly and pose a significant problem in the development of the data interfaces. Rainfall forecasts and meteorological observations used to forecast rainfall locally will be received from other systems.

Static data will also be input which includes relatively non-changing information such as model parameters, station attributes, historical data, and spatial geographic data. These large volume data will be input prior to on-line operation or changed infrequently during fair weather periods.

A data base management system (DBMS) will provide the link from the processes to the inputs and outputs. The data collection, communications, DBMS, and database structure are not discussed in detail here since they will be developed as part of AWIPS. FLASH data is input to and required from the DBMS but FLASH is designed independent of it.

4.2 Processes

In addition to the quality control, there are five principal processing components, i.e., precipitation analysis, quantitative precipitation forecast (QPF) analysis, hydrologic forecasting, a geographic information system (GIS), and a product generator (see Figure 1).

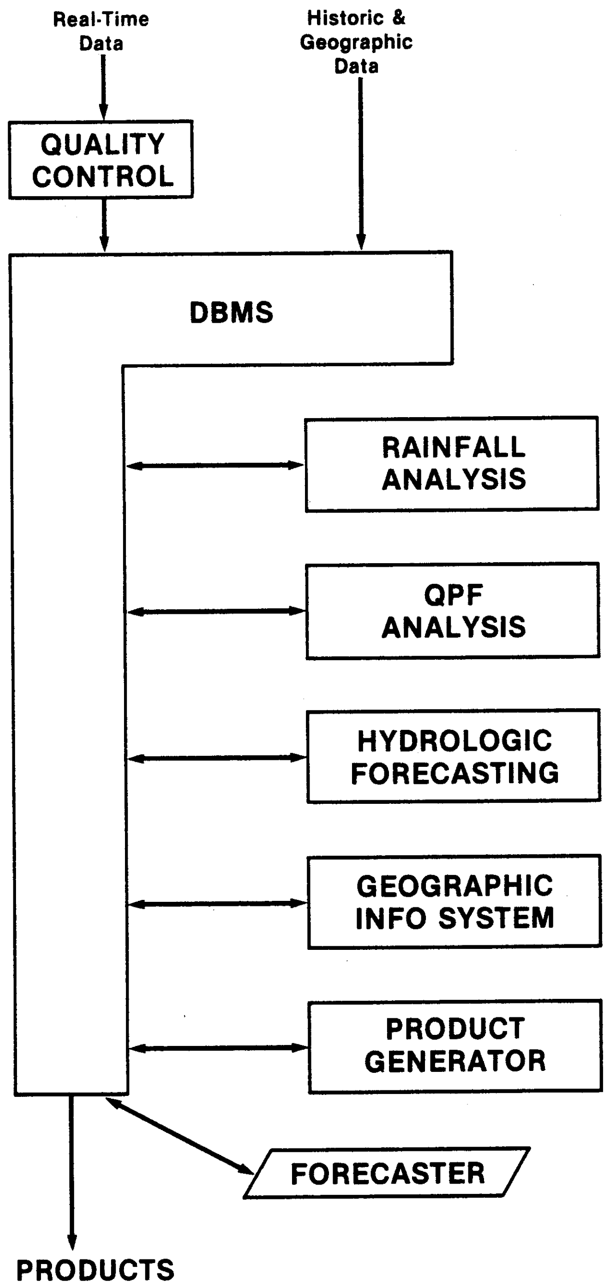

Figure 1. Overview of FLASH

All of the processing components will operate automatically and interact with each other through the DBMS. However, the option for forecaster interaction will be present in several of them.

These processes operate in sequence, with the analyses providing rainfall and QPF estimates to the hydrologic models, which then produces stream forecasts. The GIS combines the forecasts with geographic data to help assess the flood potential and create various displays. The product generator uses a decision system which considers the forecasts, error estimates, and damage potential to create computer worded warning statements.

The precipitation analysis and QPF components are shown in more detail in Figure 2. Their functions are to produce observed rainfall estimates and forecasts of rainfall, respectively, with error estimates for the entire area of responsibility. Rainfall estimates with high space and time resolution will be produced using an existing technique (Krajewski and Crawford, 1982) which merges any available data (i.e., gage observations, radar, and satellite rainfall estimates) in a statistically optimal fashion. Various QPF's are available (Georgakakos and Hudlow, 1983) and the QPF used will probably be a blend of several. These may include forecasts from other systems, such as a short term NEXRAD projection and QPF from large scale models, and an internal QPF produced from a precipitation model with local meteorological observations or forecasts. The QPF blend concept needs to be developed and is likely to require decisions by the forecaster.

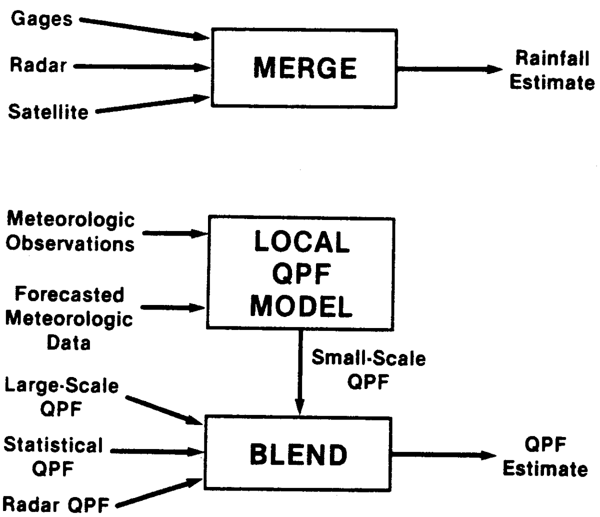

Figure 2. Precipitation (upper) and QPF (lower) Analysis

Precipitation from the analysis will be input to hydrologic forecast procedures to produce flood forecasts. As shown in Figure 3, there will be three levels of forecasts produced from the hydrologic models, i.e., general area-wide, ungaged flow, and site specific stage forecasts. The three levels are designed to add increased site specific information considering the time and data limitations. The initial analysis will be area wide to give a general early warning. Individual stream forecasts for small basins within the general warning area will be accomplished with ungaged flow forecasts. Stage forecasts are designed for critical areas with supporting river gage information.

The area-wide analysis indicates probability of flash flooding over general areas such as a county. Probabilities will be determined by comparing rainfall and associated error variances with rainfall criteria estimated to cause flooding (Zevin and Davis, 1985). River stage forecasts will be produced with an existing rainfall-runoff model and predetermined model parameters. One modeling system being investigated is the Integrated Hydrometeorological Forecast System (IHFS) (Georgakakos and Hudlow, 1985), which uses an automated filter mechanism to update the initial model conditions and produces error estimates with each forecast. Ungaged flow forecasts will be produced with some synthetic hydrologic technique (Viessman, et al., 1977) that utilizes spatial data from the GIS, e.g., land use, soil type, and

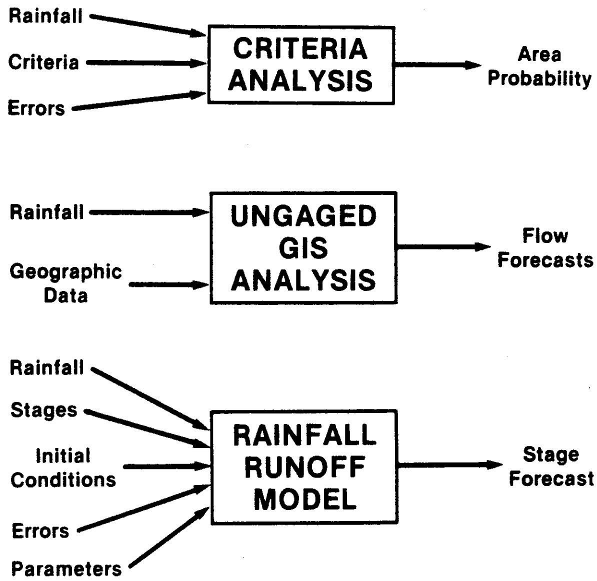

Figure 3. Three Levels of Hydrologic Forecasting

The GIS will also combine forecasts from the hydrologic component with historic and spatial data to assess the flood damage potential and create various displays (see Figure 4). Inundation and damage potential displays will be produced for individual sites using stage forecasts, elevation data, and historical flood-damage information. A categorical assessment of the flood magnitude, (e.g., minor, moderate, major, record flooding) will be made for ungaged streams using the flow forecasts and regional flood-flow estimates. These will be used to create displays indicating the location, timing, and categorical magnitude of flooding. Urban flood potentials will also be defined by comparing rainfall amounts with certain design rainfall frequencies for cities. Development of the GIS may be expedited by taking advantage of recent work on hydrologically oriented GIS's (e.g., Ragan and White, 1985).

The product generator will use a decision system to decide which products are needed and when to issue warnings, based on consideration of the hydrologic forecasts, error estimates, flood damage potentials, and pre-set decision rules (see Figure 5). Products will be formatted into computer worded statements ready for review by the forecaster. Application of "expert systems" (Racer and Gaffney, 1984) and computer wording for flood forecasting will be investigated within the NWS.

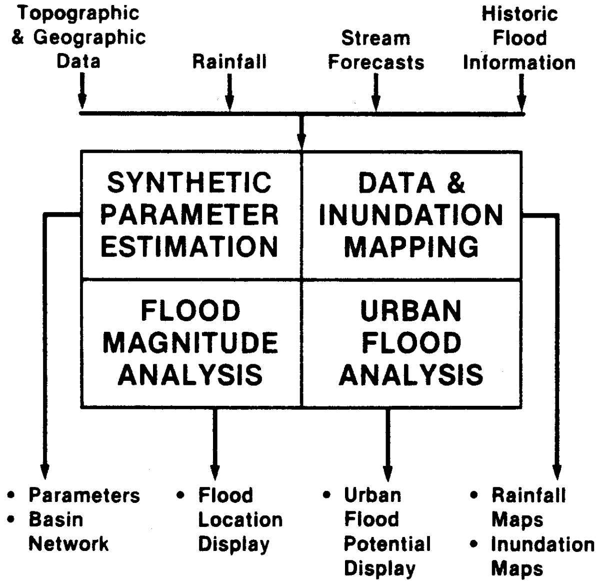

Figure 4. Structure of the Geographic Information System (GIS)

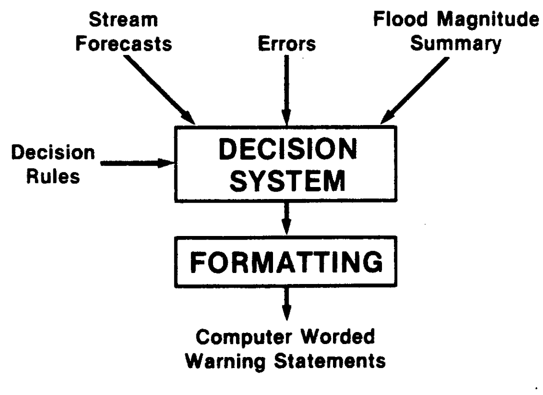

Figure 5. The Product Generator

4.3 Output

The ultimate product of FLASH will be concise flash flood warning statements for public dissemination. Warnings may contain various levels of information concerning the location, magnitude, and time of flooding. Early warnings will indicate general areas where flooding is imminent and particular high risk locations. These will be followed by warnings for individual streams, including stage forecasts and categorical flood magnitude statements.

Although the warnings will be produced automatically, the forecaster must make the final decision on product dissemination. Therefore, other outputs will be available to provide forecaster interaction with the system prior to issuance of the final warning. Rainfall displays and summaries will allow the forecaster to assess and select the data used in the objective analysis of precipitation and QPF. Error estimates will be output with each flood forecast to provide a level of confidence for the forecaster. Geographic displays (showing general area flooding with high-risk areas, categorical flood assessments for individual streams, and site-specific inundation levels) will be included to make the forecaster more aware of the situation and better able to respond to public needs and inquiries.

5. CONCLUSIONS

One goal of the National Weather Service is to provide advance warning of flash floods with a sufficient degree of accuracy. This paper describes a proposed design of a system, FLASH, to meet that goal. FLASH actually will be a subsystem of an advanced interactive processing system planned for nationwide implementation in National Weather Service field offices.

High resolution rainfall data will be collected from a variety of sources, including gages, radar, and satellite. These data will be analyzed using rainfall analysis and hydrologic forecasting techniques, which are now being developed. These forecasts will be combined with historical and geographic information to analyze the flood risk and damage potentials. Finally, warning products will be output indicating the location, magnitude, and time of flooding for general areas and individual streams.

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