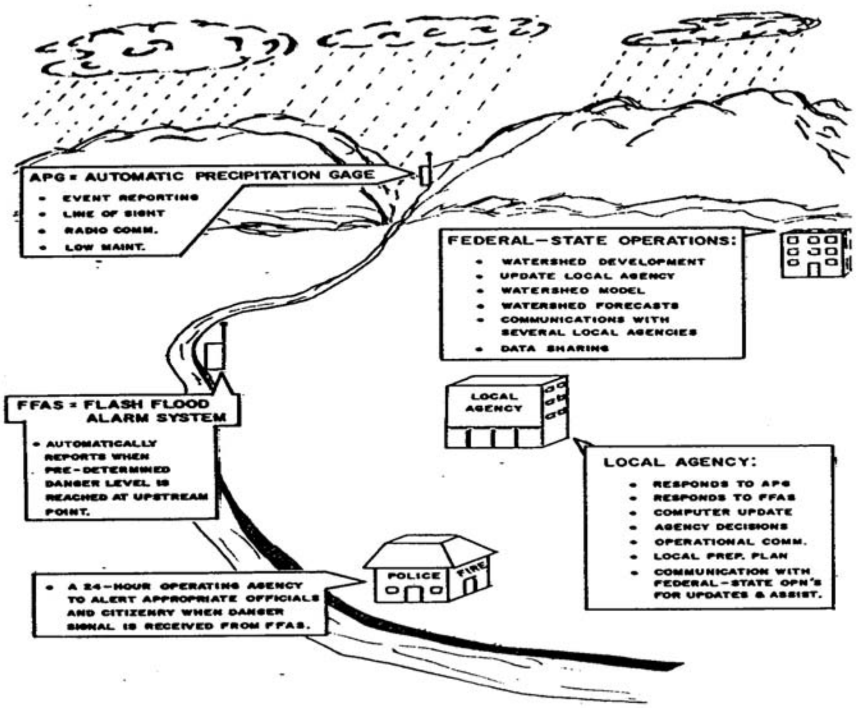
US Army Corps
of Engineers
Hydrologic Engineering Center

Proceedings of a Seminar on

Local Flood Warning - Response Systems



10 - 12 December 1986
Asilomar
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14. ABSTRACT
A seminar on Local Flood Warning - Response Systems was held on 10 - 12 December 1986 at the Asilomar, Pacific Grove, California. The objectives of the seminar were to better define the role of the Corps of Engineers and identify needed research in the planning, design, and implementation of local flood warning - response systems. Fifteen papers were presented representing federal, state, and local government agencies and the private sector perspectives. Two group discussion periods were also held.

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Local Flood Warning - Response Systems

10 - 12 December 1986

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State of Arizona
International Hydrological Services
Flood Loss Reduction Associates
City of Napa
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FOREWORD

The seminar on Local Flood Warning - Response Systems was sponsored by The Hydrologic Engineering Center, U.S. Army Corps of Engineers. It was held at Asilomar, Pacific Grove, California, on 10-12 December 1986. The seminar included participants from federal, state, and local government agencies and the private sector.

The seminar provided a forum to present and exchange views for two primary objectives. The first objective was to define the potential role of the Corps of Engineers in the planning, design, and implementation of local flood warning - response systems. The second was to identify research needs.

The presentations on the first day centered about the present and future roles of federal, state, and local government agencies and the private sector in implementing local flood warning - response systems. The state-of-the-art of flood forecasting techniques, an overview of emergency response plans, four case examples, and a description of a self-help program were presented on the second day. The third day included a paper on feasibility investigations of local flood warning - response systems and an overview of the Local Flood Warning - Response System Federal Interagency Coordination Committee.

Two panel discussion periods were also conducted during the seminar. The first was held on the second evening and discussed the initial objective of the seminar; the role of the Corps of Engineers in the planning, design, and implementation of local flood warning - response systems. The second panel discussion period was conducted as the last session of the seminar and concentrated on the second objective; the identification of needed research. Papers presented at the conference and summaries of the panel discussions are bound in this document.

SUMMARY AND CONCLUSIONS

Papers and discussions at this seminar focus on the role of federal, state, and local agencies and the private sector in the planning, implementation, and operation of local flood warning - emergency response plans. Specific objectives were to: (1) better define the Corps of Engineers' role in planning and implementation of local flood warning - emergency response plans and (2) identify needed research activities. The summary represents a compilation of information presented and discussed in the seminar sessions and informal social periods. The views expressed by the participants in their papers and the conclusions documented in the summaries do not represent the official policy of the Corps of Engineers.

Local flood warning - emergency response plans consist of coordinated actions involving flood detection and forecasting, warning dissemination, emergency response, post-flood recovery and reoccupation, and continuous plan management. The flood warning - emergency response plans consist of hardware, technical activities, and formal and informal arrangements and commitments to performance in which the human element is a vital part. Federal, state, local governmental agencies and the private sector organizations that conduct programs and operations relevant to local flood warning-response systems are numerous and diverse.

The type and sophistication of the appropriate measures can vary significantly due to physical characteristics of the stream system, the nature of the problem to the threatened area, resource availability, and institutional factors. The event response and management of a flood disaster, instead of the permanent (long-term) event control or damage potential modification, are unique characteristics of local flood warning - emergency response plans that differentiate them from other flood loss reduction measures.

The National Weather Service (NWS), which is responsible for issuing flood forecasts, has 13 River Forecast Centers located throughout the country which apply forecasting methods to predict flood stages for major streams. Although most of the NWS's flood forecasting resources are directed towards major streams, the NWS has sponsored (primarily as an advisory role) the installation of 600 manual, 80 flash flood, and 30-50 ALERT flood detection systems for counties and communities. The NWS also uses information from these systems to assist in their flood forecasts for major streams. The NWS is presently defining its policy for assisting communities in developing local flood warning - emergency response plans.

Other government agencies and the private sector have varying roles in the planning, implementation and operation of local flood warning - emergency preparedness plans. The Federal Emergency Management Agency has the primary responsibility for the Nation's emergency preparedness as related to natural and man-related disasters. Their role in assisting in the development and implementation of local flood preparedness plans has to date been limited. The Soil Conservation Service has responsibilities for planning and implementing elements of local flood warning - emergency plans and actions. As documented at this seminar, states' roles are varied, but have generally been limited in scope and assistance to local communities.

Elements of the private sector are taking an increasingly active role in the planning, design, and implementation of local flood warning - emergency response systems. In addition to their expertise, they offer the capability to provide comprehensive solutions and timely implementation that federal and state agencies have generally not provided to local communities. The Harris County, Texas flood warning system presented at the seminar, which won an award from the American Society of Civil Engineers, is an example of local government agencies using the private sector to assist in designing and installing a state-of-the-art flood warning system.

The Corps of Engineers performs analysis and implements elements of flood warning-response systems under several types of studies and programs. They include flood loss reduction studies, floodplain management services, water control, dam emergency evacuation planning, and emergency operations programs. These activities clearly demonstrate the capabilities and responsibilities of the Corps in performing evaluations of implementing local flood warning - emergency preparedness plans. Specifically, the Village Creek and Mount Airy case examples presented in this seminar and the on-going studies by other Corps District offices, demonstrate a growing awareness of the viability of local flood warning - emergency preparedness plans and commitment to their implementation when determined feasible.

Opportunities for the Corps to study and implement local flood warning - emergency response plans exist under the present framework of its flood loss reduction investigations. They may be investigated as interim measures until other structural and nonstructural measures are installed, as integral components of other measures comprising a comprehensive plan, or as stand-alone measures if other alternatives are not feasible. Interim implementation provides near-term benefits and public perceptions of early-on assistance in reducing flood losses. The feasibility of interim implementation for existing authorized studies and projects may be studied under a separate 205 study similar to the Passaic River Basin investigation. However, new studies should contain authorizing language that permits early implementation until other measures are constructed. If other structural and nonstructural measures are found to be unfeasible, it seemslikely that some elements of local flood warning - emergency preparedness plans will be justified as stand-alone measures.

The feasibility investigations of implementing local flood warning - emergency preparedness plans should be comprehensive, in particular with regards to the response actions which constitute the economic and social benefits of enhanced actions. The evaluation procedures are similar to those required for other measures. However, since the cost of the studies are likely to be large when compared to the relative low implementation cost, a reconnaissance study level of detail to determine the feasibility seems appropriate. The economic benefit analysis stream, or project life should normally be in the range of 10-15 years. For interim implementations it should not be longer than to the completion of construction of the more permanent measures.

The assessments of institutional arrangements and capabilities of a local community to operate and maintain a viable flood warning - emergency response plan is an important study factor. Numerous agencies are typically involved in conducting operations during a flood threat. The local agencies are normally better founded for development of the specific arrangements, particularly with regards to the response plans. Their involvement may be considered as part of their cost sharing obligation.

The Flood Plain Management Services Program of the Corps offers opportunities to assist local communities in implementing local flood warning - emergency preparedness plans. The States Assistance Program, for example, could be used to identify and prioritize communities needing these types of measures. Technical assistance in alerting communities to the attributes of local flood warning - emergency response plans and available resources for assistance in implementing the measures seems to be a viable aspect of the Flood Plain Management Services Program. The Flood Plain Management Services Program could also assist in conducting the study for a community. Greater national emphasis needs to be placed on the self-help program being performed by the Baltimore District as presented in this seminar.

Primary research needs identified by the seminar were means of tailoring flood forecasting related hardware and software to local community conditions and requirements, better forecasting analysis capabilities, and guidance for procedures for determining the feasibility of local flood warning - emergency preparedness plans. Standards for precipitation and streamflow monitoring hardware and data communications are needed to enable consistency in equipment for flood forecasting operations.

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LOCAL FLOOD WARNING SYSTEMS

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1. INTRODUCTION

A recent update of the National Weather Service (NWS) data base on local flood warning systems (LFWS) has revealed a significant increase in automated community LFWS's. This activity can be attributed to aggressive marketing by vendors, an increase of literature on the benefits of LFWS's, and strong involvement by the NWS. More specifically, the LFWS's have emerged from technological development by the NWS and sharp reductions in the price of computer hardware.

As flood damages continue to increase (current moving annual average flood damages are near $4 billion) and as flooding continues to affect a greater portion of the growing population in the nation, communities with persistent flood problems or communities vulnerable to great losses when flooding does occur are continually seeking methods to mitigate flood losses. LFWS's are an attractive solution because of the low cost, flexibility of operation (i.e., operate as "black box" and alarm of impending flood or can generate a complicated water balance based on precipitation analysis and hydrologic models), and because LFWS's can enhance the operation of other flood mitigation methods, such as floodgate operation, flood insurance, or flood plain zoning.

It seems evident that the popularity of automated LFWS's will continue since they "sell themselves" for effectiveness in the communities' total flood mitigation effort.

The current rapid growth can present problems which, if not addressed early, can produce larger more complex problems later. This paper provides insights into key problems and issues which could inhibit the future usefulness of these systems.

2. THE NEED FOR A LOCAL FLOOD WARNING SYSTEM

Flooding varies in frequency and magnitude. A minor flood may cause only an inconvenience, while a major flood (such as the record flooding that hit Virginia, West Virginia, Maryland, Pennsylvania, and Louisiana last November) can result in loss of life and extensive damage. If the threat from flooding is persistent, or the potential losses significant, community officials should take steps to mitigate flood losses. Installing an LFWS is one effective step that can be taken to reduce flood losses.

An LFWS is defined as a community or locally based system consisting of volunteers; rainfall, river, and other hydrologic gages; hydrologic models; a communications system; and a community flood coordinator responsible for issuing a flood warning. Figure 1 shows a typical automated LFWS. The purpose of the system is to provide emergency service officials with advance flood information that can be readily translated into response actions. LFWS's vary from simple manual systems to state-of-the-art automated systems.

TYPICAL AUTOMATED LOCAL FLOOD WARNING SYSTEMS

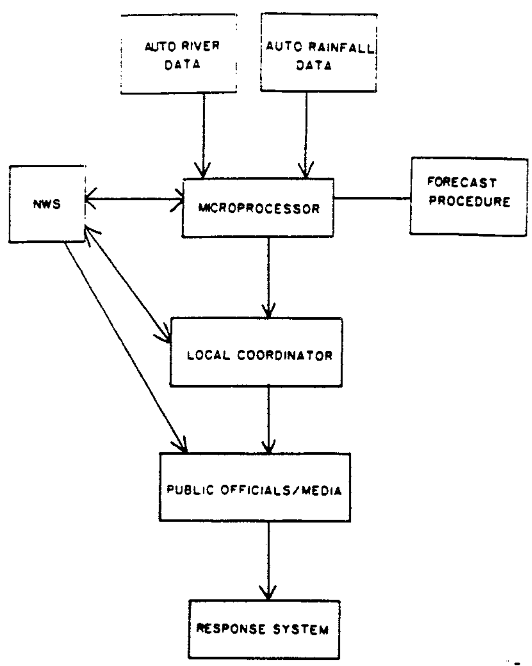

Figure 1. Typical Automated Local Flood Warning System

Many factors influence a community's decision that an LFWS is needed, and what type of LFWS is appropriate to meet their needs. These factors include the hydrologic characteristics of the watershed, the frequency of flooding, the flood loss potential, the relationship of warning time to benefits, the need for other hydrologic capabilities, community interest and awareness, and the cost of the system. Among the factors which affect the type of system selected are the desired accuracy and reliability of the system. Extensive information on the factors which determine the need for and selection of LFWS's can be found in the recent publication "Guidelines on Community Local Flood Warning and Response Systems," 1985.

3. TYPES OF LOCAL FLOOD WARNING SYSTEMS

The two basic classifications of LFWS's are manual systems and automated systems. Figure 2 shows the locations of all types of LFWS's.

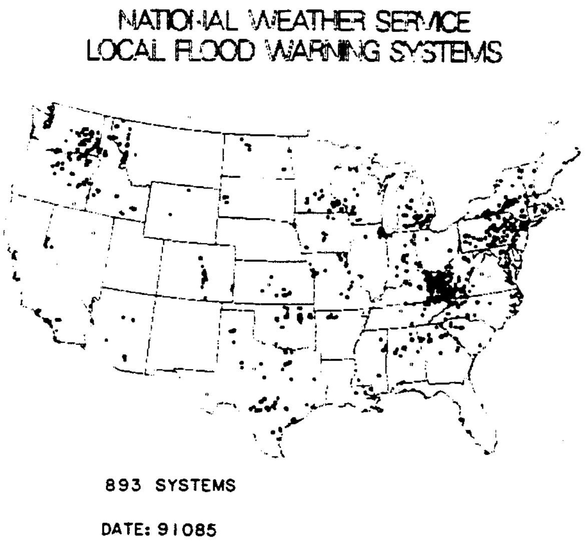

Figure 2. Local Flood Warning Systems

3.1 Manual Local Flood Warning Systems

A manual system consists of volunteer observers and inexpensive equipment to collect rainfall and river gage data. Plastic rain gages are frequently used by volunteer observers who report rainfall amounts by telephone to a community flood coordinator. A flood forecast procedure is used by the coordinator to translate rainfall that occurs over the watershed to a flood crest forecast. Procedures consist of tables, graphs, or charts that use average rainfall, and a flood index to provide flood prediction. Normally, the NWS River Forecast Centers provide the community with the forecast procedures and the updated flood index values. Once a forecast has been determined by the coordinator, and coordination with the local NWS Forecast Office has occurred, the coordinator notifies the local officials responsible for response action. Manual systems far outnumber automated systems throughout the country. There are currently 538 manual LFWS's in operation. (See Figure 3. Manual Self Help Systems.) They are simple, inexpensive, and encourage a high level of community involvement. However, they are not as accurate as automated systems and they depend on volunteers who have a high turnover rate and are often unreliable.

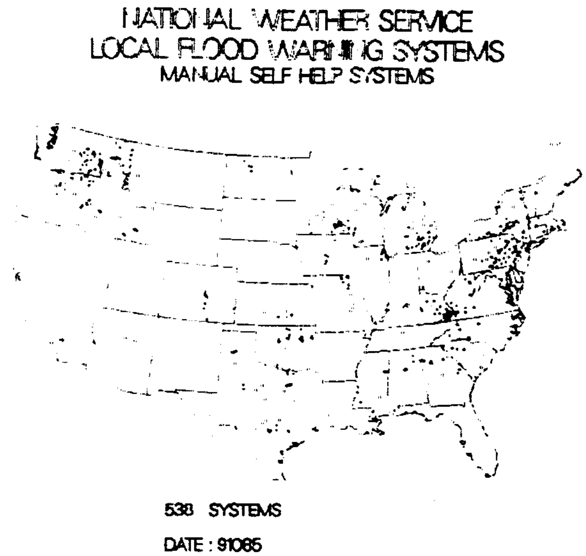

Figure 3. Manual Self-Help Systems

3.2 Automated Local Flood Warning Systems

Automated LFWS's consist of: automatic reporting river and rainfall gages; a communications system; automated data collection and processing equipment; a microprocessor; data collection, analysis and forecasting software; and a warning distribution system.

Automatic rainfall gages report rainfall every time a 1 mm tipping bucket tips. This is known as event-type rainfall sampling. For river stage, every time a change in stage of a preselected increment is measured, the new river stage value is transmitted from the sensor to a base station.

Automated LFWS's vary in design, capability, and operation. An assessment of needs must be conducted by a community to determine the level of sophistication (and associated costs) required. Automated system operation may vary from a simple flash flood alarm gage that audibly announces imminent flooding, to a continuous computerized analysis of precipitation and streamflow and a hydrologic model to forecast flood levels. There are about 150 communities in 20 states which are now operating or planning to install automated systems.

Automated LFWS's are now primarily designed, developed, and implemented by private vendors. The NWS does provide a basic automated system which cannot be supported in real time.

3.3 Flash Flood Alarm Gages

Flash flood alarm gages consist of water level sensor(s) connected to an alarm or light located at a community agency that operates around-the-clock. River stages which exceed a preset level trigger the alarm. Flash flood alarm gages can use phone lines or radio transmission.

3.4 ALERT

The Automated Local Evaluation in Real Time (ALERT) system is a typical automated LFWS developed by the NWS California-Nevada River Forecast Center in Sacramento, California. The ALERT system consists of automatic reporting river and rainfall gages, a communications system based on line-of-sight radio transmission of data, a radio receiver, and a microprocessor. Data analysis and display software is available to process, display, and control the quality of data. In addition, a hydrologic model is available to provide streamflow simulation capabilities.

The ALERT system is now principally available via private vendors and is being adopted by a number of communities throughout the nation. The ALERT system has grown into a hierarchy of capabilities from sensor criteria alarming to multi-sensor graphical plots.

3.5 IFLOWS

The Integrated Flood Observing and Warning System (IFLOWS) is an example of a network of automated systems. IFLOWS is a cooperative Federal, State, and local effort in Appalachia. IFLOWS is now operational in 80 counties and is planned for operational mode in over 100 counties by 1987. The county systems consist of automatic reporting rain gages, radio repeaters or relays, a backbone distribution system (the communication system architecture varies in each State), a radio receiver, a microprocessor, and system software. All of the counties are linked to a State Emergency Operation Center, surrounding counties, and NWS offices so that rainfall data or flood information can be rederived from any county, State, or NWS office.

4. DATA

The increase in sensors associated with automated LFWS's is presenting a potential problem of developing multiple data formats, which will severely restrict the use of sensor data to all the users that need the data. A valuable lesson was learned from the Geostationary Operational Environmental Satellite (GOES) Data Collection Platform (DCP) Program. Before GOES DCP standards were developed, a total of 29 different data formats for 29 different types of platforms created a nightmare for GOES data users. A high communications processing overhead in software (multiple decoders) is now required to obtain GOES data. LFWS sensor data format issues include of the need for standard mark and space frequencies, the need for a check byte and parity bit, the way different sensors are identified in the data message for a given site, and the need for battery voltage information.

Another data issue is the need for data exchange between automated LFWS's, or between community systems and external users. For instance, a community automated LFWS may be collecting data that is needed by an adjacent community. This capability has been developed as part of IFLOWS but is severely limited for ALERT systems and flash flood alarm gages. In addition, the NWS has the need for automated LFWS data and needs to know when sensor criteria has been exceeded for warning purposes. However, ALERT system software must be modified, and an NWS "receiver/polling" system developed, for this capability to be realized. The NWS is currently designing a Forecasting and Local Analysis System for Hydrology (FLASH) which will provide this requirement for the early 1990's, but a standard approach must be defined long before that.

In most instances, hydrometeorological data collected by automated systems, such as 1 mm precipitation data and 0.5' river stage data, is archived at the site. This function is necessary for the ongoing calibration of the hydrologic models for the model portion of the system.

These data are only archived to meet a short-term local need and are usually not available for use by other communities, State, or Federal agencies or universities. Data will be lost unless arrangements are made to centrally archive the rapidly increasing operational data base.

5. MAJOR ISSUES

The proliferation of automated system sensors, different hardware and software configurations, multiple hardware and software vendors, and multiple users of automated system data has presented unique, important problems and issues which require the attention of Federal, State, and local agencies. These problems and issues can be system categorized into the broad elements of hydrologic models, operations, and institutional standards.

5.1 Hydrologic Models

The adequacy of hydrologic model operation has always been an issue in establishing automated LFWS's. Which hydrologic model to use can be a difficult choice, as there is a balance between using simplified, less accurate models vs. more sophisticated yet complicated models. Simplified models are easy to use but are not yet available to communities. Sophisticated hydrologic models require a fairly high level of hydrologic knowledge, both in the calibration of the models and the tuning or adjustment of the soil-moisture state variables. Both the initial calibration and the ongoing maintenance of parameters and state variables are extremely important to the accuracy and reliability of an automated LFWS.

What about the conflict in forecasts that may result when the community executes a hydrologic model that yields different output (forecasts) than the NWS models yield? Who resolves conflicting forecasts? Who is liable for forecast accuracy? model calibration? These questions have not been answered at this time.

5.2 Operations

An automated LFWS is only one of many non-structural methods to mitigate floods. There are many structural and non-structural methods which, when coordinated in an overall comprehensive effort, can produce synergistic results and outperform each separate method. For example, the operation of floodgates can be optimized if an LFWS is established.

The performance of an automated LFWS is a function of the data inputs, type of model used, quality of the calibration of parameters, and hydrologic knowledge to utilize model output properly. In most instances, uncertainty in a flood forecast is due to uncertainty in determining the spatial and temporal rainfall distribution. Automated LFWS usually collect data from sensors only within the local area and do not have benefit of river and rainfall gage data available elsewhere, such as data collected by the NWS. Also, remote sensed precipitation data (e.g., radar or satellite data) are valuable for assessing rainfall distribution for areas where rainfall gage data are missing. These additional data are available at the local NWS office but are not available to users on an automated basis. Some defined level of real-time coordination is necessary between the local NWS office and the community LFWS. This defined level is somewhere between what a community desires and what the NWS is capable of delivering, considering manpower resources. Figure 4 is an overview showing the complex interaction of factors which must be defined before there is a rapid growth in automated systems.

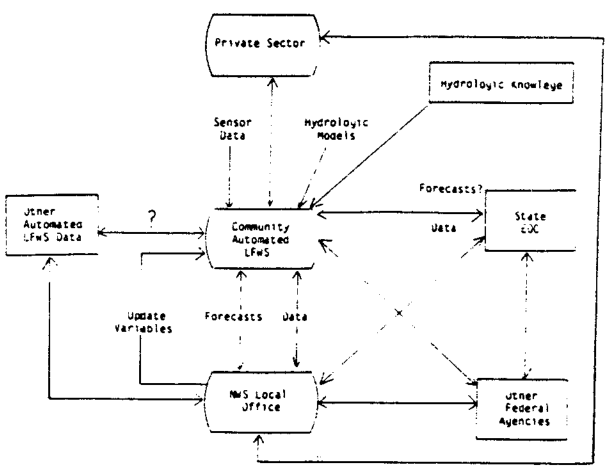

Figure 4. Local Flood Warning Systems Interactions

5.3 Institutional Standards

Currently, there are no institutional standards, policies, or guidelines as to what elements constitute an effective automated LFWS. Specifically, information such as the type of models available, parameter or variable calibration requirements, maintenance requirements (hardware, software, enhancements, and parameter updates), number and type of drills to be conducted, etc. is not available to communities seeking it. Lack of standards of excellence could lead to operational failure of an LFWS and needless flood losses.

6. INTERAGENCY COOPERATION

The NWS is addressing many of the problems and issues stated earlier in this paper. A technical working group was established to develop standards for automated LFWS's. A recently developed "white paper" by the Office of Hydrology is being distributed to the various vendors in an attempt to provide uniform standards for sensor data formats and communications protocol exchange between various microcomputers.

In November 1982, an Interagency Work Group on Local Flood Warning Systems was established by the Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data. This work group was tasked to write a report for community officials which would answer the following questions: (1) How does a community determine the need for an LFWS? (2) What types of LFWS's are available for use?, and (3) What types of federal and state aid are available for communities seeking assistance? The report, entitled "Guidelines on Community Local Flood Warning and Response Systems," was recently distributed to State and Federal agencies.

Recently, a Standing Interagency Task Force on Local Flood Warning and Response Systems (LFWRS) was established to address many of the issues surfaced in this paper. More specifically, the task force will review and establish LFWS standards, evaluate LFWRS, coordinate research and development connected with LFWRS, and provide a focus for information exchange on LFWS. The agencies represented on this task force are the National Weather Service, Tennessee Valley Authority, Federal Emergency Management Agency, Corps of Engineers, Soil Conservation Service, Bureau of Reclamation, U.S. Geological Survey, Department of Housing and Urban Development, and the National Park Service

In 1986, the Standing Interagency Task Force on Local Flood Warning and Response Systems, in cooperation with the Association of State Flood Plain Managers, will hold short courses on LFWS's for State and local officials. Many issues raised in this paper, as well as additional problems, will be discussed during those courses.

7. CONCLUSIONS

There is now a strong Federal and State effort to resolve many issues associated with the rapid expansion of automated LFWS's. Federal agencies that deal with flood mitigation are seeking joint solutions to growing LFWS problems. The states are also cooperating in an effort to maximize the use of a growing data base and realize the potential for a network of automated systems which could significantly reduce flood losses. Nonetheless, many issues such as data archiving and distribution, operational coordination of warnings, and liability will require a great deal more attention and resources.

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LOCAL FLOOD WARNING SYSTEMS

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Appendices:

* * * * *

1. Background. The National Weather Service (NWS) is facing a dilemma in meeting the growing needs of communities requesting assistance in developing local flood warning systems (LFWS). A local flood warning system is defined as a community or locally based system consisting of volunteers, rainfall, river and other hydrologic gages, hydrologic models or procedures, a communications network and a community flood coordinator responsible for issuing a flood warning. Local flood warning systems are classified as manual or automated. Currently the NWS provides specific flood forecast and warning services for over 3,100 communities in the United States. With approximately 900 LFWS's in operation in 1985, nearly 4,000 communities in the Nation are now receiving site-specific flood warning services. The Federal Emergency Management Agency has determined that 20,000 locations in the Nation are flood prone. The remaining 16,000 communities receive warnings through general county-wide flash flood warning services. These services are limited because of a lack of data. The data problem occurs because many of the 16,000 communities are located on small, flashy streams which may crest in a period ranging from a few hours down to less than 1 hour following the occurrence of heavy rainfall. Very little lead time is available in these situations to warn residents. Because of the scarcity of hydrologic data in these river

basins and because floods occur in such short time periods, the NWS is presently unable to provide specific warning service to these vulnerable communities.

LFWS's offer communities maximum potential benefits in a flood warning service. Various types and levels of sophistication of LFWS's exist to meet community needs. Because community officials recognize the value of an LFWS and because the NWS has increased its community awareness publicity program, the demand by communities for LFWS's has increased significantly. Many state, county, and local governments are turning to the NWS for assistance. Also some communities are, in essence, setting up their own LFWS, which may or may not meet their needs. The demand for assistance in implementing LFWS's continues to increase. In order to meet its basic flood warning mission, the NWS must be prepared to respond to this growing problem.

2. General Policy. Recognizing the importance of LFWS's in improving flood warning service to communities, the NWS will continue to provide technical assistance to communities to the extent resources are available. The main objectives of implementing LFWS's are: (1) to provide communities with an effective warning system and thus reduce the risk of disaster and (2) to provide a data base to the NWS to support the NWS flood and flash flood warning program. NWS resources will be directed to support only LFWS's that meet both of these objectives. When providing technical assistance to communities, the NWS will: (1) ensure data collected by the system are made available to the appropriate NWS office(s) in as near real time as possible; (2) require coordination between cooperators and the NWS in providing real-time flood forecasts and warnings; (3) encourage development and use of an emergency action plan by cooperators; and (4) clearly define the responsibilities of the NWS and cooperators with regard to the design, installation, implementation, operation, and maintenance of the LFWS. In this policy, the term "cooperator" usually refers to the community but can include agencies such as the Corps of Engineers or Federal Emergency Management Administration.

NWS offices are limited in staff and monetary resources. Each community request for NWS technical support should be evaluated carefully in determining the permissible level of involvement. The meteorologist in charge of the Weather Service Forecast Office (WSFO) and the hydrologist in charge (HIC) of the servicing River Forecast Center (RFC) should coordinate with each other before any commitment is made external to the NWS.

The basic NWS philosophy behind an LFWS is that it is a cooperative venture between the Federal Government and a cooperator with a requirement for a flood warning system. The types of LFWS's are described in Appendix A. As explained in that appendix, many of the systems have evolved in the past few years to take advantage of new electronics technology.

The Memorandum of Understanding (MOU) between the NWS and the cooperator (see Appendix B for examples) is established to set forth the responsibilities of the NWS and the cooperator.

NWS assistance to communities consists of:

(1) recommending alternative LFWS's to meet the economic capabilities of the community and

(2) supporting the system depending on the type of LFWS chosen and the NWS's available resources.

Communities are usually in the best position to understand their local flood problems, to observe events during flood periods, and to take appropriate action to limit flood losses. During a flood event, LFWS's provide a cooperative basis for local officials and the NWS to work together efficiently to produce reliable, timely local warnings. In the event communication fails between the community and the NWS, local officials should have enough information to act independently.

In general, the cooperator is expected to procure, install, maintain, and operate all LFWS equipment necessary to meet its requirements. The NWS will procure, install, maintain, and operate only that equipment necessary to provide data from LFWS's directly to appropriate NWS office(s) in a usable format and only if funding is available. The MOU states, in concise terms, the NWS's warning responsibilities and how these responsibilities are to be integrated into the operation of the LFWS. Prior to any NWS procurements or software development pertaining to an LFWS, a fully executed MOU will be in place. The MOU must require the cooperator to develop an emergency action plan and to work with the NWS to ensure appropriate data, forecasts, and warnings are exchanged. The MOU should also spell out as clearly as practicable the technical support to be provided by the NWS, as well as the specific responsibilities of both the NWS and the cooperator with regard to design, procurement, installation, operation, and maintenance of the LFWS.

3. NWS Office Responsibilities.

3.1 Office of Meteorology. The Office of Meteorology (OM) is responsible to see that activities of LFWS's integrate into the overall watch/warning activities of the NWS. OM is also responsible for direction and technical support of preparedness for floods and flash floods. Additional OM activities include preparation of training materials for area managers, MIC's, OIC's, and warning preparedness meteorologists in coordination with the Office of Hydrology (OH). OM also has the responsibility, working closely with OH, to develop a national flash flood verification program.

3.2 Office of Hydrology. OH is responsible for providing overall guidance and coordination for LFWS's at the National Headquarters. This includes: setting national standards for LFWS's including data formats, software compatibility, and functional characteristics of both software and hardware, and providing technical guidance to the OM in formulating model emergency action plans and training material for local offices to assist in LFWS's. These activities include preparation of training materials for area managers, MIC's, OIC's, and warning preparedness meteorologists. OH will coordinate the NWS role with the headquarters of various Federal agencies.

3.3 Regions. Regional Directors are responsible for implementation of this policy and overall management of LFWS's. This includes training, planning, and allocation of resources to provide assistance to cooperators (state, county, or municipal governments), where possible, in establishing them. The Regional Director will be the responsible NWS agent to sign MOU's with cooperating agencies.

3.4 Weather Service Forecast Office (WSFO). The WSFO is responsible for issuing flash flood watches for state and county warnings, and therefore must have access to real-time data and forecasts generated by LFWS's. The area manager of the appropriate WSFO is responsible for coordinating NWS assistance to communities. The WSO, RFC, regions, and WSH will support the area manager in meeting this responsibility. This includes maintaining any equipment installed in an NWS office and belonging to the NWS. Coordination and support will be required from the RFC's, WSO, regions, and OH. It is necessary for the WSFO/WSO to have access to real-time LFWS hydrologic data and forecasts to support the NWS flash flood watch/warning program. The WSFO can offer the flood coordinator (the community official responsible for collecting hydrologic data, generating a flood forecast, if appropriate, and disseminating the warning to community officials) currently available information during the flood event, such as quantitative precipitation forecasts, radar, and satellite information. The WSFO can also offer rapid preparation and dissemination of warnings back to the cooperator's area threatened by flooding. As stated earlier, this is one of the primary reasons for implementing an LFWS. The WSFO will be responsible for rapid dissemination of warning messages developed either within that office or in conjunction with the cooperator. The area manager is also responsible for ensuring that interagency coordination occurs. Interagency coordination refers to coordination with the state flood plain management or emergency services officials and any local federal agency involved in the system implementation.

3.5 Weather Service Office (WSO). The WSO is responsible for county flash flood warnings and must therefore have access to real-time data and forecasts generated by LFWS's in its area of responsibility. The WSO may also assist in the implementation of LFWS's. The WSO will be responsible for rapid dissemination of warning or alert messages developed either within that office or in conjunction with the cooperator.

3.6 River Forecast Center (RFC). The RFC assists the community through the WSFO in implementation of an LFWS as resources permit. The RFC role in terms of technical support varies according to the type of LFWS involved. For the manual self-help system, the RFC provides assistance to the WSFO and community in the site selection of the hydrologic observation network and development of hydrologic procedures to forecast floods and provides real-time headwater advisory and flash flood guidance to the appropriate WSFO/WSO.

For automated systems, the RFC can provide assistance to the WSFO and community in the site selection of the hydrologic observation network; provide generic automated local flood warning system standards for hardware, software, and hydrologic models to a requesting community; act in an advisory capacity to the community for the calibration of hydrologic models; coordinate radio frequency usage; assist in the composition and evaluation of an emergency action plan; monitor and evaluate system performance.

For flash flood alarm gages, the RFC assists the WSFO/community in site selection of the gage(s), technical advice on the location/operation of the base station, and general monitor and evaluation of the system performance. The RFC must have access to real-time data and forecasts from the LFWS to support the flood forecast program. The RFC's furnish guidance products to the WSFO/WSO, such as flash flood guidance, headwater advisory guidance, and downstream crest forecasts.

RFC technical support may be limited by the availability of personnel and time. Each request by the community or WSFO should be evaluated individually, and the level of involvement of the RFC should be determined by the HIC.

Types of Local Flood Warning Systems (LFWS)

A.1 General Information.

There are two basic types of LFWS's: manual and automated. These are described below. Both manual and automated systems are designed to make full use of local skills. They offer a range of options in cost and technical complexity to fit the local situation. Experience with automated systems is growing rapidly. This experience is described below in terms of Automated Local Evaluation in Real Time (ALERT) systems that were first developed on an individual community stand-alone basis and Integrated Flood Observing and Warning Systems (IFLOWS) that is being developed to serve many communities on an area-wide basis in Appalachia. The same technology is used in both ALERT and IFLOWS.

A.2 Manual Self-Help LFWS's.

Most of the LFWS's in operation today are manual self-help systems. These systems are inexpensive and simple to operate. However, if not well managed, they can become extremely personnel intensive and very expensive to operate. The manual self-help system is comprised of a local data collection system, a community flood coordinator, a simple to use flood forecast procedure, a communication network to distribute warnings to appropriate emergency/response officials, and an emergency/action plan (see exhibit E-12-A1).

The simplest and least expensive approach to data collection is to recruit volunteer observers to collect rain and stream gage data. Inexpensive plastic rain gages are supplied to volunteer observers who report rainfall amounts to a community flood coordinator. The flood coordinator must maintain the volunteer rainfall networks and plastic rain gages. More sophisticated automated rain gages may be necessary in remote areas or in situations where observers are not available. Stream gages also vary in sophistication from those receiving site observations (i.e., tape down points, staff gages, etc.) to remote observations (i.e., telemarks, satellite, radio, etc.).

The River Forecast Center (RFC), at the request of the meteorologist in charge/area manager, can provide the flood coordinator with a simple, easy to use forecast procedure. These procedures normally consist of tables, graphs, or charts which compare observed rainfall with an index for flooding as input and provide a flood forecast as output (see exhibit E-12-A2). These indices to flooding are determined by the RFC and provided to the Weather Service Forecast Office and Weather Service Office as well as the cooperator. Flood forecasts vary from a categorical forecast of flooding to a numerical crest value. Forecasts may also include the time remaining before flood stage will be reached or the time when the crest will occur. Once a forecast is generated, the coordinator should then contact the responsible National Weather Service (NWS) office for final coordination.

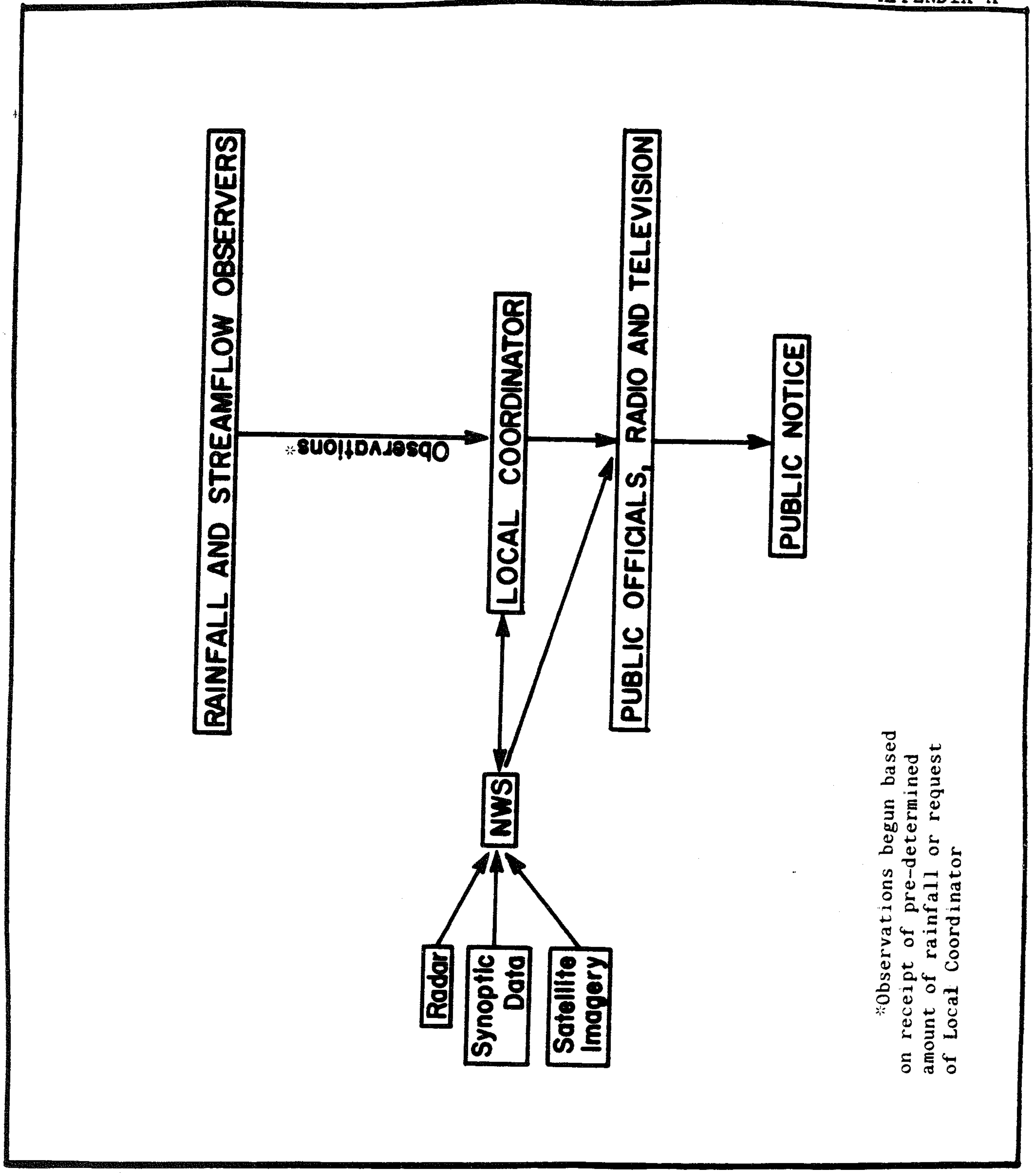

Exhibit E-12-A1: Schematic of a Typical Manual LFWS

LOGAN CR - PENDER NE FLOOD ADVISORY TABLE

FLOOD STAGE IS 20.0 FEET

LAG FROM END OF TIME PERIOD OF HEAVIEST RAIN TO CREST IS 12 HOUR(S).

	STAGE FEET	DISCH. CFS	6 HOUR RAINFALL AMOUNTS (INCHES)									
	15.0	10400	0.7	1.1	1.5	2.0	2.4	2.9	3.3	3.8	4.2	4.7
	16.0	12120	0.7	1.2	1.6	2.1	2.6	3.0	3.5	4.0	4.4	4.9
	17.0	13840	0.8	1.3	1.7	2.2	2.7	3.2	3.6	4.1	4.6	5.1
	18.0	15560	0.9	1.4	1.8	2.3	2.8	3.3	3.8	4.3	4.7	5.2
	19.0	17280	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	5.4
FS	20.0	19000	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
	21.0	24350	1.2	1.7	2.3	2.8	3.3	3.8	4.3	4.9	5.4	5.9
	22.0	29700	1.4	1.9	2.5	3.0	3.6	4.1	4.6	5.2	5.7	6.3
	23.0	36466	1.6	2.2	2.8	3.3	3.9	4.5	5.0	5.6	6.1	6.6
	24.0	43233	1.9	2.5	3.0	3.6	4.2	4.8	5.3	5.9	6.5	7.0
	25.0	50000	2.1	2.7	3.3	3.9	4.5	5.1	5.6	6.2	6.8	7.3
	26.0	57500	2.3	3.0	3.6	4.2	4.8	5.4	5.9	6.5	7.1	7.7
	27.0	65000	2.6	3.2	3.8	4.5	5.1	5.7	6.3	6.9	7.4	8.0
	28.0	72500	2.8	3.5	4.1	4.7	5.3	6.0	6.6	7.2	7.8	8.3
	29.0	80000	3.1	3.7	4.4	5.0	5.6	6.2	6.8	7.5	8.1	8.7

PEAK UNITGRAPH ORDINATE = 31000 CFS FLOOD STAGE R.O. = 0.61 IN.

INSTRUCTIONS

THE AMOUNT OF RAINFALL REQUIRED TO PRODUCE FLOOD STAGE APPEARING IN THE RFC ADVISORY FIXES THE APPROPRIATE COLUMN OF RAINFALL--CREST STAGE VALUES TO BE USED DURING THE ENSUING PERIOD. ENTER THE TABLE AT THAT COLUMN AND FOLLOW UP OR DOWN TO THE AVERAGE OBSERVED RAIN TO OBTAIN THE CORRESPONDING CREST STAGE. USE ALL AVAILABLE RAINFALL REPORTS IN THE BASIN ABOVE THIS STATION AND AVERAGE.

EXAMPLE..THE RFC ISSUES AN ADVISORY THAT 2.0 INCHES IS THE AMOUNT OF RAINFALL THAT WILL PRODUCE A FLOOD STAGE AT THIS STATION. THAT NIGHT AN AVERAGE OF 3.0 INCHES OF RAIN FALLS OVER THE BASIN ABOVE THIS STATION. ENTER THE TABLE ABOVE WITH A VALUE OF 2.0 AT FLOOD STAGE, 20.0 FEET. FOLLOW DOWN THAT COLUMN TO 3.0 AND READ A STAGE OF 24.0 FEET. THE LAG TIME SHOWN AT THE HEAD OF THE TABLE IS 12 HOUR(S). SO THE PREDICTION IS A CREST OF 24.0 FEET, 12 HOUR(S) FROM THE END OF THE PERIOD OF HEAVIEST RAINFALL.

NOTE.....THIS TABLE IS BASED ON THE ASSUMPTION OF UNIFORM RAIN OVER THE BASIN FOR A PERIOD OF 6 HOURS. DOWNSTREAM AND/OR MORE INTENSE STORM CONCENTRATIONS WILL CAUSE CRESTS ONE TO TWO FEET HIGHER AND MUCH SOONER. UPSTREAM AND/OR LESS INTENSE STORM CONCENTRATIONS WILL CAUSE CRESTS TO BE LOWER AND LATER. THE CREST ESTIMATE IS PRELIMINARY AND APPROXIMATE, AND IS SUBJECT TO LATER REVISION BY THE RFC, IF HYDRO-METEOROLOGICAL CONDITIONS WARRANT.

MAXIMUM STAGE OF RECORD 23.1 2/19/71

LOGAN CR - PENDER NE MKC RFC SEP 1984 OMA WSFO

Exhibit E-12-A2: Sample Flood Forecast Procedure

A.3 Automated LFWS's.

In the past decade, a substantial growth in technology and a decrease in the cost of computer systems have resulted in the development of automated flood warning systems. The specific systems that have evolved so far are described below. There are many private vendors now marketing automated LFWS's.

A.3.1 Flash Flood Alarm Systems.

Flash flood alarm gages consist of water level sensor(s) connected to an alarm or light located at a community agency with 24-hour operation. Water levels exceeding one or more preset levels trigger the alarm. The alarm is located upstream of the community. The lead-time warning is given when the alarm sensor is set at a pre-determined critical water level. Exhibit E-12-A3 illustrates the installation of a typical flash flood alarm gage. Communication between the gage and base station can be achieved by a dedicated land line or via radio waves. Flash flood alarm gages can also be used as part of the manual and automated LFWS's as described below.

A.3.2 Automated Local Evaluation in Real Time (ALERT).

The ALERT system was developed by the California-Nevada River Forecast Center in Sacramento, California. This system consists of automated event reporting river and precipitation gages, automated data collection and processing equipment, a hydrologic model, hydrometeorological analysis, and processing software, as well as communications and display software.

The precipitation gages are modular, self-contained event reporting units. A tipping bucket mechanism (1mm) causes transmission of a radio signal containing the station identifier and an accumulated precipitation value. The river gage is a simple event-reporting unit which transmits preselected incremental changes in river elevation. The same electronics and radio package used in the rain gage is utilized with the river gage. Both are powered by self-contained batteries.

Data collection and processing hardware consist of a radio receiver to collect event reported radio signals and a dedicated microcomputer system. Radio transmissions from the gage locations to the local agency are line-of-sight.

The data collection system operates continuously in a fully automatic mode, receiving data and processing information for display to the user, including precipitation maps. The Sacramento streamflow simulation model can provide updated streamflow forecasts every 12 minutes.

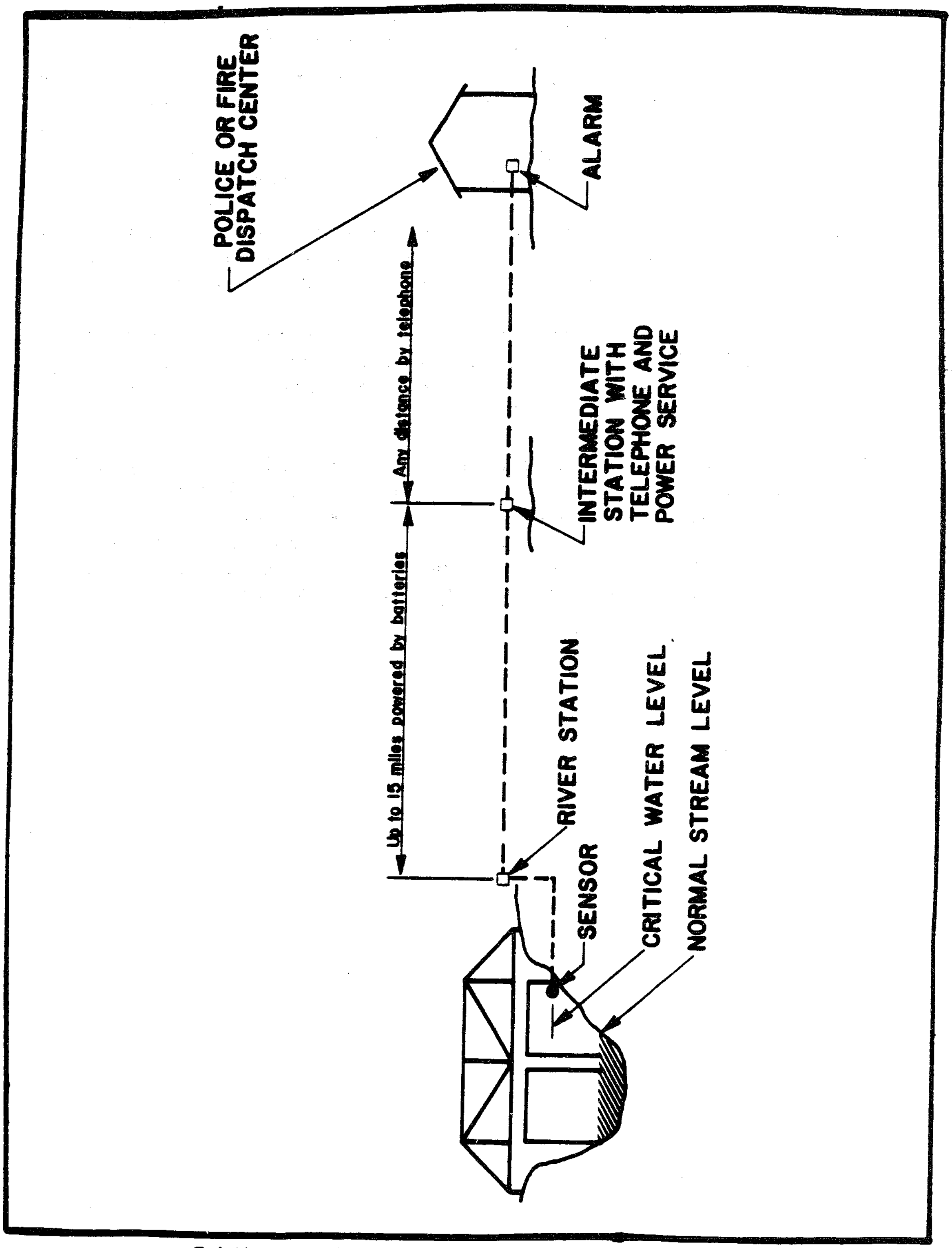

Exhibit E-12-A3: Typical Flash Flood Alarm Gage

A.3.3 Integrated Flood Observing and Warning Systems (IFLOWS).

The NWS in cooperation with the Appalachia Regional Commission, the Tennessee Valley Authority, and the States of Kentucky, Virginia, Pennsylvania, West Virginia, and Tennessee has implemented a prototype IFLOWS. This system combines event-reporting sensors, data and voice communications, and minicomputer technology to each county in a 100-county region.

Data, forecasts, and warning products are distributed to state and county authorities responsible for the provision of emergency services to people in flood-threatened areas. NWS offices are directly linked to IFLOWS.

The sensors trigger the transmission of radio signals that include the station identifiers and values of the monitored parameters. The sensors and transmitters are powered by batteries and are independent of commercial power sources.

Radio transmissions from the sensors are line-of-sight to strategically located receivers. Data are then relayed by microwave radio to the dedicated, central processing minicomputer. The counties/communities can receive data, forecasts, and warning products over this same communication system from the minicomputer. IFLOWS operates continuously to monitor local conditions for the counties and for NWS offices in the IFLOWS region.

Specific Memoranda of Understanding

This appendix contains guidelines for constructing a Memorandum of Understanding (MOU). The first MOU is for a community sponsored flood warning system that can be applied to an automated LFWS, such as Automated Local Evaluation in Real Time or flash flood alarm systems. The second MOU pertains to manual self-help systems. While these MOU's are primarily to be used as guidelines, the basic content and intention of these samples should be contained in any MOU between the NWS and a cooperator.

MEMORANDUM OF UNDERSTANDING FOR COMMUNITY SPONSORED AUTOMATED FLOOD WARNING SYSTEM

This Memorandum of Understanding between the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) and the County of __________________ is undertaken for the purpose of defining a mutual assistance program designed to develop an Automated Flood Warning System for the County of ____________________.

1. Authority

The NOAA, National Weather Service undertakes this Memorandum of Understanding pursuant to its authority in 15 U.S.C. 313, 15 U.S.C. 1525, and 7 U.S.C. 450b, in order to carry out its functions relating to flood warnings.

2. Nature of Agreement

The Flood Warning System is being implemented in high risk flash flood areas. The system utilizes state of the art techniques that can be incorporated into an operational flood warning program. The overall concept calls for Federal, state, county, and municipal cooperation.

The NOAA, National Weather Service and the County of will cooperate to accomplish the installation and operation of an Automated Flood Warning System to help provide advance flood warning for the County of _____________________.

3. Responsibilities of the NOAA, National Weather Service

The NOAA, National Weather Service shall:

a. Assist the County of _____________ and State of ______________ officials to identify the need for specific equipment for the warning system.

b. In coöperation with other agencies as necessary, provide standards for automated local flood warning systems.

c. Assist community officials in the site selection of hydrologic gages and consult with Federal, state, local or private vendors on the calibration of hydrological models.

d. Provide training for county flood coordinators and municipal officials. The scope of the training shall cover:

1. NWS Flood/Flash Flood Watch/Warning Program,
2. Municipal Flood Warning Programs,
3. Operation and maintenance procedures for communications and hydrologic instrumentation,
4. The need for emergency response planning, and
5. Periodic drills to test the program.

e. Issue, according to the severity of the hydrometeorological threat, flash flood watch, flash flood warnings, or Local Statements.

f. In conjunction with the Federal Emergency Management Agency, assure that the activities of the Automated Flood Warning System are coordinated with designated municipal, county, state, and Federal disaster officials.

g. Be responsible for obtaining Federal Communications Commission approval of the necessary radio equipment frequencies.

h. Assist in the site location of the field equipment and train the personnel in its operation.

i. Provide forecast advisory service for the selected river basins.

j. Provide system monitoring and consult with the community concerning forecast model recalibration needs, as required.

4. Responsibilities of the County of ______________________

The City shall:

a. Initially, pay for the capital cost of flood warning equipment and all installation costs with the exception of river staff gages and manual rain gages.

Long term, pay for the capital cost of major equipment replacement or upgrading, where necessary for the continued necessary operation of the flood warning system.

The funding by the County of the operational and capital costs is conditional on the availability of appropriated funds within the County budgets.

Flood warning equipment may include any combination or all of the following.

1. Telemetered receiver, printers, and minicomputer systems,
2. Telemetered rain gages,
3. Radio repeaters for radio-telemetered,
4. Flash flood alarms, and
5. Telemetered river gages.
6. Software installation and model calibration

b. Operate, maintain, and assume recurring costs for those portions of the program of the Flood Warning System including:

   1. County operations center, including utilities and physical space.
   2. Equipment used to support the County program, including telemetered river and rain gages, flash flood alarms, minicomputer systems, radio equipment, data receivers, repeater system, staff gages, and plastic rain gages.
   3. Communications and utility costs to support the County activities.

c. Designate a County Flood Warning Coordinator by title to be trained in and responsible for the operation of a County preparedness plan.

d. Prepare a County preparedness plan to detail the necessary responsible actions to be taken, including coordination with the National Weather Service whenever river and rainfall data indicate a possible need for statement and/or warnings. The plan will recognize that all flood warnings, including flash flood warnings, are to be initiated by the National Weather Service except when, in the judgment of the County Flood Warning Coordinator, an emergency situation exists and time does not permit consultation with the National Weather Service. At such times, the Coordinator may issue a warning to the public and local officials prior to informing the National Weather Service.

e. Establish a County communication and action center to operate continuously, or as required for the purpose of:

1. Operating the automated data receiver and mini-computer communication center, where applicable.

2. Receiving and recording all reports of rainfall and flood conditions.

3. Promptly relaying or making available all such reports to the designated Municipal Flood Warning Coordinator.

4. Serving as the official distribution point for all warnings and statements issued by or for the designated County Flood Warning Coordinator.

5. Ensuring, in addition to general public distribution, that flood warnings or statements reach warning action points as listed in the County preparedness plan.

6. Relaying river and rainfall reports, flood data, and warnings to the National Weather Service Office in ____________ as soon as practicable after local requirements have been satisfied.

5. Title to Equipment

Title to equipment purchase under this Memorandum of Understanding shall remain vested with the County of ____________________.

6. Amendments or Modifications

This Memorandum of Understanding may be amended or modified by mutual agreement of the NOAA, National Weather Service and the County of ______________.

7. Termination

This Memorandum of Understanding may be terminated by either party upon sixty (60) days written notice to the other party, notice to begin with date of mailing.

a. Upon termination, all equipment listed by the National Weather Service as accountable shall be returned within sixty (60) days to the National Weather Service in the condition it was at the time of termination.

8. Effective Date

This Memorandum of Understanding is effective as of the last date shown below upon execution by both parties hereto.

Cooperator Identification

By: ____________________

Title: ________________

____

United States Department of Commerce
National Oceanic & Atmospheric Administration
National Weather Service

Prepared by:

______________ Weather Service Forecast Office

Address: ____________________________

____

____
Meteorologist in Charge

Approved by:

National Weather Service
Director, ________ Region Headquarters

____
Signature

MEMORANDUM OF UNDERSTANDING
MANUAL LOCAL FLOOD WARNING SYSTEMS

This Memorandum of Understanding entered into on by and between the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) and the Community of ______________________________ for the purpose of providing a Flash Flood Alerting System for the community.

1. Nature of Agreement

The Community of ___________ and the National Weather Service will cooperatively install and operate a local warning system to help provide advance flood warning for the community.

2. Responsibilities of the NOAA, National Weather Service

The NWS will:

a. Develop a self-help forecasting procedure as data becomes available for specific drainage basins and provide a copy to the community and other public safety officials along with instructions for its use.

b. Cooperate with other agencies so that the forecasting procedure may be responsive to all available information.

c. Instruct volunteer river and rainfall observers.

d. The National Weather Service through the Weather Service Office at ________________ will issue, according to the severity of the hydrometeorological threat, flash flood watch, flash flood warning, flood warning, special weather statement, or severe thunderstorm warning.

3. Responsibilities of the Community

The community of _________________ will:

a. Arrange for volunteer rainfall observers.

b. Install river and rainfall gages, with maintenance of same.

c. Provide a communication center operating 24 hours/day as required to maintain a continuous collection of rainfall and flood data, these reports are relayed to the Weather Service Forecast Office _______________ when significant amounts of rain are reported and to the local authorities responsible for official action during flood events.

d. When emergency conditions and lack of time prevent warnings being issued by the Weather Service Office ______________________, the designated official(s) of the community will be prepared to use the self-help forecasting procedures and issue Flash Flood Warnings and immediately notify the WSFO ________________________.

e. The community communication center will disseminate all flood forecasts and warnings, including revisions, issued by WSO.

f. The Civil Defense Communications Center will be the official flood warning disseminator for all the City of _______________________

g. Establish a flood emergency action plan.

4. This Memorandum of Understanding may be amended or modified by mutual agreement of the NWS and ______________________________.

5. This agreement may be terminated by either party upon 30 days written notice to the other party, notice to begin with date of mailing.

Department of Commerce, NOAA
National Weather Service

By:______________________________

Title:____________________________

By:______________________________

Title:____________________________

STATE ROLES IN FLOOD WARNING

By Leslie A. Bond[1]

Introduction.

In general, states have not yet defined or assumed their roles in providing flood warning. Flood forecasting and warning on the major river systems in the country has generally been beyond the capabilities of the states, leading to forecasting by Federal agencies. However, individual communities and organizations based on watersheds have developed forecasting and warning systems with little or no state support.

This paper will concentrate on the types of activities which are generally appropriate for states and the factors which a state should consider in determining its role. It will conclude with examples of state roles in different types of warning systems.

It will be seen that a state may assume roles in the planning of flood warning systems, preparedness planning, data collection, warning dissemination or combinations of these activities. Thus far, states have only attempted to fill in gaps between local and Federal activities.

Other types of governmental entities and public agencies may assume roles very similar to those described herein for states. For example, the Susquehanna River Basin Commission has developed one of the foremost flood warning systems in the country (Susquehanna River Basin Commission, 1979). Regional planning authorities, water supply utilities and special districts might have sufficient authorities and geographical area to provide services which are beyond the capabilities of local government.

Factors in Determining a State's Role in Flood Warning.

In considering a flood warning system, there are several factors which determine the type of system and the division of responsibilities among the providers and users of the warnings. Most of these factors must be considered when determining a state's role.

The Nature of the Required Warning. The flood prone area and its uses cause a wide variation in flood warning needs. These needs vary from the closure of roads when the depth of flooding makes passage dangerous to the evacuation of major populations and floodfighting. In some cases, the warning and response is most appropriately carried out by the population at risk, while in others, all levels of government, private industry and various individuals should cooperate.

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1 Chief, Nonstructural Measures Section, Arizona Department of Water Resources, Phoenix, Arizona.

The Nature of the Flood. Two primary flood charac-teristics which impact warning needs are the time to onset of the flood and the areal extent of the flood. Again, these characteristics determine which actors are involved in warning and response activities.

Political Boundaries. The number and relative size and capabilities of the political subdivisions within the watershed and within the flood prone areas affect the relative roles of Federal, state and local governments.

Funding. The sources and amount of funding have a very basic effect on the roles of various governmental elements.

Roles Which States May Assume.

Effective flood warning includes emergency response planning. A comprehensive flood warning and response system can be divided into four major elements (Owen and Wendell, 1981):

1. Flood recognition (forecasting) activities;
2. Warning activities;
3. Preparedness plans; and
4. Maintenance.

Incorporating the factors listed above into the components of the system leads to the appropriate role(s) for a state to assume.

Flood recognition activities can range from casual observation of current flooding conditions to sophisticated computer modelling of stream systems, watersheds and weather. These activities usually include data collection, data assembly and data analysis.

Much of the data needed for flood recognition may be collected by different agencies. Data may not be available in a timely way for flood forecasting due to data collection methods. Data collection systems designed for other purposes may be incomplete for flood forecasting purposes. Data may not be in a form which is useful for flood forecasting. Most flood forecasting procedures require computerized data. Evaluation of the current data collection systems and their adequacy and applicability to flood recognition may be an appropriate state role.

In a large rived basin, where a state-wide data collection system is needed to provide adequate flood forecasting, the state may be the appropriate agency to operate a data collection system to integrate data available from other sources and collect additional data as needed.

It is important to realize that agencies collect data for their own purposes and usually under very specific mandates. It is not unusual to discover that these agencies are reluctant to cooperate with other programs, even those whose objectives may be to save lives during disasters. If an agency has a system working, it may not be possible to modify that system. In some cases, it may be necessary to duplicate data collection efforts in order to meet the needs of flood recognition.

Data assembly is a major undertaking for large watersheds with data from a variety of sources. Data must be assembled at a place and in a form which makes analysis possible. This involves data telemetry and formatting, usually to fit the requirements of a computer-based analysis system. Data assembly may be an appropriate role for the state.

Data analysis for flood forecasting purposes is frequently a highly technical activity. There are many flood routing models and many rainfall/runoff models. Those which produce the best results in terms of both accuracy and timeliness are sophisticated and require a high level of expertise to calibrate them for the watershed and/or the storm. Data analysis may be an appropriate state role.

Flood warning activities should translate the flood forecast into information which can be used by the population at risk to reduce its susceptibility to the flood threat. These activities include: a) determining whether the prediction developed through the flood recognition system warrants issuance of a warning; b) deciding the specific warning message to be issued; and c) delivery of the warning message to its intended recipients (Owen and Wendell, 1981). These activities must be largely determined in the establishment of the flood recognition activities discussed above and the preparedness planning discussed below.

Generally, the issuance of flood warnings should be made through the National Weather Service (NWS). They have statewide communications systems and direct input to the mass media. In some cases, however, it may be desirable to develop more detailed warnings which are to be delivered to specific users. It may be appropriate for the state to examine the NWS warning system and enhance it as needed.

The preparedness plan is an essential part of the flood warning and response system and the state may assume a large role. An effective preparedness plan will be well integrated with the flood recognition and warning systems. State emergency services agencies are usually involved in assisting communities in the preparation of the community plans and can assist in this integration. Since the preparedness plan will include activities for government, industry and individuals, it should serve as the basis for the establishment and operation of the entire system. That is, the preparedness plan defines the need for flood forecasts, and the planned response defines the nature of the warning. If the state is to assume any role in flood warning it should make certain that it is reflected in all affected preparedness plans within the state.

Maintenance is obviously a function of the other roles assumed by the state. It may include maintenance of data collection and telemetry equipment, recalibration of forecasting models and periodic review of preparedness plans. It should be included in planning for any state activity in flood warning.

Determining the State Role.

The state role in flood warning, as in most undertakings, is determined by need, authority and funding. If a need for flood warning is perceived by the state, the authority and funding may be developed. The state role is ultimately determined by the state's willingness to act relative to the willingness of other agencies.

The need for flood warning at the state level is generally identified as a result of a flood disaster or a series of disasters. If the state is lucky, that identification will arise from a "near miss" or a disaster in another state. Formal analysis of the need for a state-wide flood warning system will probably be initiated by a state agency, either of its own volition or at the request of several communities. This process will lead to considerations of system design, cost and staffing. An examination of current capabilities of all levels of government and the private sector to meet these needs will point out the deficiencies and the most likely agents to meet these deficiencies.

The authority for the state to undertake flood warning is almost entirely in the hands of the state legislature or executive . In some cases, it may already exist under the broad authority of emergency preparedness. In other cases, it may require specific legislation or executive action. If new authority is sought, it should be tied to funding for the flood warning effort.

Funding actually determines the extent and nature of the state's role in flood warning. Flood warning requires dedicated, highly trained staff, equipment and facilities. These resources may provide other services to the state during non-emergencies, but their first obligation must be to flood warning.

In a complex technical undertaking such as a flood warning system, someone has to "drive the car." Many aspects of a flood warning system can be, or in some cases, must be accomplished through the cooperation of many people and agencies. However, someone must make decisions on priorities and many of the technical decisions, and the person or agency who makes them will invariably be the one with the best funding.

A state-wide flood warning system requires funding for the purchase, installation and operation of data collection equipment; the purchase, installation and operation of receiving and data analysis equipment; and the staffing for system design, installation and operation. Although the type of system will vary the costs, the funding level is not insignificant. Even if the system is to be installed in segments, there is a relatively large start-up cost. For the first piece of data collection equipment to function properly, some elements of the design, installation, operation, analysis and maintenance systems must be in place.

Theoretical Examples of State Roles.

1. A small watershed where flash flood warning is needed. In a watershed which is small enough that the primary concern is flash flooding, local government may be driving the car, and the state role may be minimal. The state may assist in preparedness planning and design of the system. They may assist in funding the installation and operation of the system. However, the actual operation, and generally the maintenance, of the system will usually be a local responsibility because of time restraints. This is because when the time from the onset of the storm to the onset of flooding is short, the responsible agency must be responsive on a 24-hour basis. The agency most likely to be available for this is the local police agency, or in larger communities, the emergency services staff. It is difficult for a state to staff for one or two flash flood systems.

2. A state-wide warning system for large rivers. Where warning is needed for large rivers, either the state or a Federal agency may drive the car. State involvement may be limited primarily to support of forecasting performed by Federal agencies such as the National Weather Service, the U.S. Army Corps of Engineers and the Bureau of Reclamation.

In this case, the state may take the lead in identifying locations where forecasts are required, funding the installation of data collection and telemetry equipment, providing staff to supplement that of the Federal agencies and ensure that the warnings generated are received and understood by the communities and populations at risk. Again, the integration of flood warning into local preparedness plans is essential.

To provide this service, the state may contract with other agencies for data collection and telemetry or it may install, operate and maintain equipment with state staff. State staff should work regularly with the communities at risk. State staff must be prepared to work on a 24-hour basis during flood threats and emergencies.

If the state is the major funding source, it will also assume responsibility for developing and maintaining forecast models, installation of data collection and telemetry equipment, operation and maintenance of the system and warning dissemination.

3. A "Hybrid" State-wide System for Flash Floods and Large Rivers. This is the most complex and costly type of flood warning system, and it goes further toward addressing all of the flood warning needs of the state. It will generally require both a state-wide telemetry system and a number of local flood warning systems.

In a state-wide hybrid flood warning system, the state must drive the car. Such a system will almost certainly be beyond the staffing and funding capability of all Federal agencies, and the scope will be beyond the needs of any one local agency.

As in the two examples above, it may be accomplished in a variety of ways, depending upon the state's needs and the capabilities of other elements of government. The state-wide telemetry system may be installed, operated and maintained by state staff, it may be contracted to a Federal agency, or it may be done by a mixture of the two. The state should assume full responsibility for installation and maintenance of the local flash flood warning systems, although in some cases they may contract with a local government agency. Operation of the local systems is automated to the greatest possible extent, and the necessary emergency operations must be left to local agencies.

State Flood Warning Systems Now in Operation.

Because of the relatively short time allowed for the preparation of this paper, the author has been unable to obtain documented information on current state programs. This summary is based upon telephone conversations with various persons familiar with state activities in flood warning. Any errors or omissions are the result of lack of information and are unintentional.

1. Arizona. The State funds a cooperative State-wide data collection system on major rivers. State staff supplement NWS staff during potential flood emergencies. Through special legislation, the State cooperated in funding one local flash flood warning system.

2. California. The State has cooperated with the NWS in funding the planning of State-wide and local flood warning systems (California Department of Water Resources, 1980).

3. Connecticut. The State and the Soil Conservation Service have cooperated in funding the planning of flood warning systems. The State takes the lead in installation and maintenance of data collection systems.

4. Kentucky. The State cooperates with the NWS in the planning and installation of the prototype Integrated Flood Warning System (IFLOWS). This system is funded to cover 140 counties in six states.

5. Maryland. The State cost-shares with communities on local flood warning systems.

6. Minnesota. The State cooperated with the National Parks Service to install one local flood warning system. The State offers to assist communities evaluate their flood warning needs.

7. New Jersey. The State has cooperated with the U.S. Army Corps of Engineers to evaluate flood warning needs.

8. New York. The State has contracted for a study to define flood warning needs.

9. North Carolina. See Kentucky.

10. Pennsylvania. See Kentucky.

11. Tennessee. See Kentucky.

12. Virginia. See Kentucky.

13. West Virginia. See Kentucky.

Conclusions and Recommendations.

The state role in flood warning has not been defined. Where states are active in flood warning programs, their activities have been prescribed by their own perceived needs and the capabilities of local and Federal agencies to provide these services. Only a few states have had any activities in flood warning, and there are no flood warning systems which address all problems within a state.

If the states are to take a more active role in flood warning, they must have incentive either from below, in the form of local demands for assistance, or from above in the form of Federal cost-sharing. If a National comprehensive flood warning program is contemplated, a valuable first step would be to conduct a survey of the states to determine their perceived need for flood warning programs and their perceptions of the capabilities of Federal, state and local agencies to meet these needs.

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ROLE OF PRIVATE SECTOR IN FLOOD WARNING SYSTEMS

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PAPER 4

ROLE OF PRIVATE SECTOR IN FLOOD WARNING SYSTEMS

by David C. Curtis

Introduction.

The question of what role the private sector should play in the development and implementation of community flood warning systems will not be totally answered in this paper or in this conference. Instead, the question is being answered now and it will be answered in the future by the marketplace.

Ultimately services offered at reasonable prices that satisfy demands expressed in the market will be purchased by consumers. Whether those services are purchased from the public or private sectors depends on how efficiently they are delivered to the consumer. Public programs that effectively satisfy demands will be supported by the electorate and funded by tax dollars. Private offerings that provide needed services will be funded directly by the consumer. The laws of natural selection prevail.

Wouldn't life be easy if it was this simple? While elementary economics may provide general guidelines for flood warning markets, day to day execution is clouded by many issues that have created an uncertain environment for everyone. And, as in any market, uncertainty inhibits the efficient and timely delivery of services.

Unfortunately, inefficiencies cost. For a flood warning system, the price of inefficiency is reflected in missed opportunities to save lives and property. With such tragic potential, it is the responsibility of all in the flood warning market to constantly examine current issues and eliminate impediments to efficient service.

Current Issues.

There is no shortage of flood warning issues to consider. Among them are:

1. Consumer needs,
2. Service,
3. Support,
4. Innovation,
5. Multi-purpose use,
6. Liability,
7. Public Safety,
8. Education,
9. Competition,
10. Economics,
11. Funding,
12. Standards.

This short list is by no means exhaustive and no significance should be placed upon the numerical order of each item. However, based on the author's experiences as both a public sector provider and a private sector vender of

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flood warning services, these are some of the more common issues raised in the flood warning market. In the limited amount of space available in this paper, it is impossible to closely examine each issue. However, they all deserve a brief comment if only to establish a better overall perspective.

1. Consumer needs. The actual needs of a consumer of flood warning services are often ill-defined. When communities do recognize the need for some sort of flood warning capability, they quite often do not have the skills or the resources necessary to define their own needs. For communities who have yet to recognize the need, the problem is even worse.

Where do communities go for help? The truth is that there aren't many places where help is available. When compared to the hydrologic design community, the pool of professionals who are familiar with state-of-the-art technology in operational flood warning systems is almost non-existent.

Even the National Weather Service's capacity in this area is surprisingly small. On a daily basis, the National Weather Service has less than 100 professional hydrologists involved in flood forecasting. However, only a small fraction (perhaps less than a dozen or so) of these skilled professionals are available through organizational position, experience, and knowledge to aid the design, development, implementation, and operation of a state-of-the-art community flood warning system.

In the private sector, the numbers are not any better. Most private sector hydrologic experience is design related, not operations related. Very few private sector hydrologists are available who have both operational hydrological experience and advanced skills in the latest flood warning technologies to provide communities with quality advice. This is particularly important when community operations must be coordinated with an agency such as the National Weather Service.

The lack of professional help for communities is as much a reflection of the relative youth of the developing flood warning market as anything else. However, as more and more communities implement and gain experience with new flood warning systems the knowledge pool grows as well.

2. Service. After a community implements a flood warning system, there is a question of service. Communities are concerned about who does the fixing when something fails. Are communities to build their own expertise from within or are they to depend upon a public or private vendor for service? If they depend upon outside service, will it be available in one, two, or five years after implementation?

The flood warning market is still young. In its current form, the market for automated flood warning systems is less than ten years old and the availability of turn-key services from private vendors is less than three years old. Some of the questions require a longer operational record before an adequate answer can be made.

What can be stated now is that the growth of flood warning system implementation is occurring at a rate that is far too fast for public agencies to adequately support. Federal budget constraints in recent years accentuate the problem. As the market grows and matures, its ability to foster private sector participation grows as well. In the future, routine system servicing if not done by communities themselves will most certainly come from the private sector.

3. Support. Post-implementation support issues are very similar to the service issues discussed above. Often, communities only assign a small number of persons to be responsible for the local flood warning system operation. Who will help them if a problem occurs that local personnel can't answer? Again, the projected numbers of flood warning system implementations will probably dictate a large amount of private sector support.

4. Innovation. The question of innovation is an exciting one. How does a community keep pace with changing technologies? The answer will likely be one that involves combinations of public and private sector influences. It is also one where all parties can be involved.

New ideas can come from the communities through their own experience and learning as the systems are used operationally. Public sector agencies can contribute through operational experiences as well as from funded research and development activities. Private vendors will continue to innovate to advance technology and reduce costs in order to protect their own competitive positions in the marketplace.

So many technologies involved in flood warning systems are still leaping ahead at spectacular rates. It's clear that the capabilities of today's flood warning systems are only scratching the surface of future possibilities.

5. Multi-purpose use. Flood warning systems, especially automated flood warning systems, being implemented today have the capability of addressing multiple purposes. Automated systems are now routinely implemented using microcomputers. The microcomputers perform real-time data acquisition, data base management, hydrologic analysis, forecasting, and control functions. Increasingly powerful microcomputers with operating systems that permit many tasks and several users to run simultaneously have created new possibilities.

Real-time data acquisition and analysis capabilities are used continuously to monitor possible flood conditions. However, the real-time data acquisition capacity of the flood warning system can easily be extended to include other purposes such as air quality, water quality, or ground water monitoring. Actually, many of these systems can be used to collect and store virtually any type of data.

The data base management ability of the new flood warning systems can be used to build a very high quality historical data archive. Real-time data for flood warning can be stored permanently and, in time, analyzed to form a basis for possible changes in local hydrologic design specifications.

Geographical information data bases may also be included to enhance the interpretation of the real-time data. These data can also be used later to support local planning and engineering functions.

Excess capacity on the new microcomputers can even be used to support non-hydrologic activities. Spread sheets, word processors, and administrative programs can be run on the microcomputers without interrupting the normal data acquisition and analysis processes.

One of the real advantages of the multi-purpose aspect of the new automated flood warning systems is that it broadens the base of support in the local community. For example, if the engineering department, the planning department, the environmental permits department all gain from the flood warning system's general capabilities, it will impart a higher priority on the project for implementation and continued support. This is especially true since the infrequent nature of major flood events often masks the perceived value of the warning system. Continuous use by several agencies breeds increased familiarity and confidence with the system which results in stronger annual support.

The multi-purpose potential of flood warning systems is a perfect entry for private vendors. Most federal agencies have narrowly defined missions making their support of multi-purpose systems difficult. Private vendors can easily customize applications that meet very specific client needs.

6. Liability. Perhaps the most volatile issue regarding flood warning systems is liability. Huge personal-injury awards granted by the courts and so called 'deep-pocket' laws have heightened the sensitivity of community leaders to the question of liability. Uncertainty abounds. No clear-cut directions have been defined by legal precedent.

Communities see that they must assume some element of risk when operating a flood warning system. However, they must assume risk for whatever activity they undertake. For example, a fifteen ton city truck used for road repair is a dangerous piece of machinery. Accidents can happen. People can get hurt. The city is at risk.

Yet, if the city did not act to repair its roads, accidents can happen and people can get hurt. The city is again at risk. In the interest of greater public safety, the city will routinely undertake the risk of operating a repair truck. One risk is undertaken hoping to reduce a potentially much larger one.

Communities do have clear authority to implement warning systems under their general mandates to protect public health, safety, and welfare. With tested flood warning technologies now available, communities may find themselves at greater risk by not implementing a flood warning system than by actually implementing one. One risk is accepted with the hope of reducing a potentially much larger one.

Private sector liability is even less well defined. The market is still too young to have a significant litigation history. Drawing from the experience of other engineering fields, however, one could reasonably conclude that as long as flood warning systems are designed and implemented according to generally accepted standards, liability exposure would be minimized.

The real liability question for the private sector revolves around standards. What are they and who sets them? Currently no well-defined standards exist for flood warning systems.

7. Public Safety. Many communities have yet to accept flood warning programs as vital elements of public safety, even where the benefits are obvious and well defined. Other components such as emergency medical technicians, 911 telephone systems, fallout shelters, search and rescue teams, road repair, street sweeping, snow plowing, etc. are all widely accepted and valued. Why not flood warning?

Part of the problem is that reliable community flood warning systems have not be in use very long. Not enough history has been developed to create the necessary legacy for acceptance. Tremendous successes with flood warning systems in Fort Wayne, Indiana ($2 million saved in one storm on an $80,000 investment) and Houston, Texas ("One of Ten Outstanding Engineering Achievements in the U.S." in 1985) are not widely publicized. Even in communities where great successes occur, the story is often soon forgotten.

The infrequent nature of severe flooding is also a contributing factor to the lack of public understanding. If no major flood has occurred in 30 years, community perceptions of flood risk are diminished. Consideration of a flood warning system is often viewed as a low priority item. An existing flood warning system's value is often questioned if no flooding occurs after implementation. Perhaps the community wonders if it over-reacted to the flood threat.

Frequent use and exposure of the flood warning system is a key to community-wide acceptance. How can this be done given the infrequent nature of major flooding?

First, a good flood warning program is used far more often than the incidence of major flooding suggests. Many more no-flood and minor flood events occur than major events. But communities don't know for sure than an event is a minor one until it is over. An automated flood warning system can help make that distinction earlier, saving the community time and money. More importantly, community flood fighting teams build credibility as responses become more accurate and timely.

Actual experience with automated flood warning systems has shown that forecasts of no flooding may be as important or even more important than forecasts of major flooding. Unnecessary evacuations have been greatly reduced and much lower overtime expenses are reported as flood fighting crews are called out only when then need is definite.

A second way to improve community awareness of the flood warning system is through multiple use. For example, use of the flood warning system for water quality monitoring, air quality monitoring, severe weather reporting, traffic control (low-water crossings) etc. promotes a higher system visibility which, in turn, breeds familiarity.

Strong contributions from both the public and private sectors are needed to foster acceptance of the flood warning system as a priority public safety device. Continued promotion of the concept, advancing technology, and the implementation of reliable working systems will demonstrate the public safety value of flood warning systems.

8. Education. Everyone must be involved in flood warning education.

Government agencies, private companies, and the public at-large need more information and continued demonstration of the value of warning systems.

For example, government agencies are frequently turned to by communities for advice. Unfortunately, there is not enough professional help to meet the needs. Private consulting firms are often retained for engineering advice. Unfortunately, there is not enough qualified professional help to meet the needs. Finally, flood warning systems as well as response strategies are not well understood by the general public.

A continuing stream of flood warning information needs to be generated by all involved in this fledgling market. It is in the best interest of public agencies whose mission elements involve flood warnings and responses to promote the concept both internally and externally. Better flood warning system utilization by the public will increase their actual and perceived value. When properly promoted, improved public perceptions will lead to better support for agency missions.

Private sector marketing strategies can also aid this effort. In marketing the concepts, private companies also heighten public awareness of flood warning system availability.

On top of the exchange of information between groups and organizations, there is an equal need to educate within. Government agencies at all levels need to become better informed. Agencies such as the National Weather Service, the Army Corps of Engineers, the Soil Conservation Service, etc. all need to create more community flood warning system expertise in order to administer their own related mission components properly. The private sector also needs to educate itself to broaden the professional pool of talent available to help and advise communities to develop flood warning systems.

9. Competition. Current competitive conditions probably cause most of the confusion and uncertainty in the market today. Consumers are confused as to who the players are. The players are confused about their changing roles. Everybody seems to be learning on the job.

Ordinarily competition in the marketplace is between private enterprises. Not with flood warning systems, however.

Competition between private companies is expected and encouraged. Innovation and price reductions introduced to gain market share benefit the consumer. The economy gains efficiency.

In the flood warning system market place, there is not only competition between private sector companies but between government agencies and private sector companies, between government agencies, and even within government agencies. Such an unusual state of affairs exists because the flood warning market is in transition.

Quite often, new technologies get started as the result of initial government research and development. Spin-offs from the work of NASA are widely acknowledged examples. Automated flood warning systems also follow this theme. For example, a small development contract let by the National Weather Service in the mid-1970's led to the event reporting technology widely used today. Similarly, early federal software development preceded more advanced offerings by the private sector. Today, intense competition is developing among several private vendors for a share of the flood warning market. Yet a number of federal agencies are aggressively competing with private suppliers.

For example, one federal agency is currently implementing a flood warning system for a community. New software is being developed for the system by the agency in spite of the fact that existing operational software is available from at least three sources in the federal and private sectors. Furthermore, the software available from other federal sources is free and the agency developing the new software is charging the community a fee for its service. In addition, the fee being charged is higher than a far more powerful and fully tested product available from the private sector.

Many similar excursions into the flood warning hardware, software, and service marketplaces by federal agencies have occurred recently and, unfortunately, continue to occur. In most cases, the interventions have been entirely unnecessary and have resulted in higher consumer costs.

Hopefully, these extremes of federal intervention will diminish as the flood warning market matures. It must diminish because communities look to federal agencies for advice. If federal agencies are encumbered by their own competing positions, any resulting judgements can and will be questioned. Communities sense the tension caused by these conflicts and feel uncertain about any pending decisions. Economic dynamics become less efficient and the customer suffers higher costs.

10. Economics. Flood warning systems are among the most cost-effective investments to reduce potential flood damages. Benefit-cost ratios of ten, twenty, and even fifty to one are easily achievable. The system in Fort Wayne, Indiana, for example, cost the city approximately $80,000. During one 1985 flood, more than $2 million in possible flood damages were prevented due to the warning system. The City's system investment was recovered twenty-five times over during the first major storm after implementation.

The economics are only going to improve. Costs are coming down and communities with warning systems are becoming more efficient in responding to flood emergencies.

From flood damage reduction potential alone, warning system are easy to justify economically. With the added consideration of multi-purpose uses and the resulting benefits, the economic foundation of these systems is even stronger. Through aggressive innovation and price competitiveness, the private sector will provide a significant positive contribution to the economic viability of flood warning systems.

11. Funding. Money is never ever the problem with flood warning systems. Priorities are. Strong statements? Maybe. But, when you examine them closely, they're true.

All communities have money. If they did not, there would be no fire trucks, no police cars, no street sweepers, no dog catchers etc. However, communities rarely have enough money to fund everything. Many worthy projects end up contending for limited resources. Priorities must be established to insure that the available funds are used most efficiently. This means that some good projects will get funded and some will not.

The important lesson to remember is that when a flood warning project is recommended for funding, it is not competing for dollars but it is competing for priority. As good as the economic benefits of flood warning systems are, economic arguments are not enough. In order to survive, flood warning systems must gain priority in the economic, political, and sociological context of each community. If this broad base of support is missing, the long term success of the flood warning system is questionable.

This is a valuable lesson for both the public and private sectors to learn. Private companies need to understand this lesson in order to successfully market their products. Federal agencies need to understand this lesson in order to successfully encourage communities to implement flood warning systems. Federal agencies also need to understand this lesson when monies are made available to communities for flood warning systems.

As strange as it may sound, federal funding for community flood warning systems may be counter-productive. It has been the experience of the author that the most successful community systems are those that were funded by the community. When a community funds its own system, it must have established flood warning as a priority and defended it within its own decision matrix against political, sociological, and economic arguments. A priority with a strong broadly-based consensus is reached. The community has a vested interest in system success. Long-term commitment and support are insured.

Frequently, when outside funding is made available and directed for use in a flood warning system, only the economic argument is solved. The conviction that results from consensus building is missing and community commitment is weak. The community has invested little and stands to lose little if the project does not succeed. Long-term support is not insured and the outlook for system performance is often poor.

The private sector must recognize this phenomenon to protect its own self-interest. Vendors must encourage and promote the kind of consensus that builds strong systems. In the long-term, successful well-run programs will do more to sell flood warning systems than the mere availability of money.

12. Standards. One of the most important areas for federal involvement in flood warning systems as the market matures is setting flood warning system standards. Currently, no official standards of operation exist. Private venders are left to there own devices to develop systems according to the perceived needs. As the number of potential venders increases, more and more options will become available for communities to chose from. Communities will increasingly look to the federal government for direction. Standards will become necessary to insure market stability. Standards will also be necessary to promote networks of compatible systems.

Private sector companies as well communities with existing systems must work together with agencies setting standards. Current product lines as well as developing technologies may be affected. Existing investments by communities in operational flood warning systems are also obviously affected.

The flood warning market is young and there is still time to create effective standards. Federal agencies should take the lead in setting standards now. Waiting too long will only risk the proliferation of multiple 'standards' and incompatible systems. The private sector and flood warning system users must also participate in the standards process.

Conclusions.

Private sector involvement in local flood warning systems is here to stay. In fact, the level of private sector involvement is going to increase rapidly because demand in the market and the enabling technology will dictate it. All federal, state, and local agencies must recognize this fact. If they don't, they will be missing important opportunities.

With private sector involvement a given, government agencies should seize the opportunity to leverage this resource to help attain their own program goals. By opening the door for more cooperation and encouraging aggressive innovation, everyone has a chance to benefit.

Nurture the opportunity. Let it grow. The payoff could be a harvest of new ideas that save lives and property.

THE GROWING CORPS ROLE IN WARNING AND PREPAREDNESS

by James R. Hanchey[1]

Introductory Remarks

This conference underscores the importance of recognizing the fundamental role that flood warning and preparedness (FW&P) does and should continue to play along with other flood mitigation measures. Many communities are beginning to rely on flood warning and preparedness as the major remedy for their flood hazard problems. It is an adjustment that is inexpensive, innocuous, and does not preclude other damage alleviation measures. Gilbert White recognized this back in 1939, as seen in the following statement, "Flood-forecasting is essential to the successful operation of most storage-reservoirs and a few protective works such as the fuse-plug levees in the Lower Mississippi flood-protection plan. It is basic in any plan for emergency-evacuation. It is highly desireable in conjunction with programs for readjustment of structures or land use. Flood-loss insurance demands effective forecasting. Complete evacuation alone among the lines of action does not include it."

This paper focuses on the relatively recent events that have broadened the Corps of Engineers role in flood warning and preparedness. It is fairly recently that the Corps has taken a leading role in the planning and design of community flood warning and preparedness systems. This paper describes 1) the extent of this new capacity, 2) the reasons for the new scope of responsibility, 3) the impediments that limit the extent of the Corps' involvement, and finally, 4) a framework is proposed for institutionalizing and enhancing these functions.

Established Corps Role in Warning and Preparedness

The Corps of Engineers established responsibility for warning and preparedness has been in at least four major areas: emergency operations, hurricane evacuation, technical assistance, and dam safety.

Emergency Operations. The Corps has had a major role in emergency flood protection and evacuation of flood victims from imminent danger of flooding. Principle Corps emergency activities include: 1) assisting in emergency rescue operations; 2) furnishing technical advice and assistance; 3) furnishing flood fighting materials and equipment, such as sandbags,

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polyethylene sheeting, lumber, rocks to stabilize levees, and moveable pumps; and, 4) inspection of permanent flood protection structures.

Hurricane Evacuation. Along these lines, the Corps has worked closely with the National Weather Service and FEMA to issue a set of guidelines for evacuation procedures. This effort has been coordinated through the Office of Floodplain Management Services, and a major product was a the 1984 publication prepared by Jacksonville District, Technical Guidelines for Hurricane Evacuation Studies.

Technical Assistance. For the most part, technical assistance activities are provided by or directed through the Office of Floodplain Management Services. Technical assistance activities include:

1) Mapping Floodplain Areas and Interpreting Floodplain Maps. In addition to the floodplain mapping done as part of planning studies, the Corps does considerable work for the Flood Insurance Administration in preparing flood insurance rate maps. Floodplain Management Services offices throughout the country provide considerable assistance in identifying whether specific properties are in floodplain locations and what modifications may have to occur for development to be in compliance with the FIA rules. This mapping effort is important for identifying which properties would be at greatest risk during a flood and where to concentrate warning and evacuation efforts.

2) Technical Information and Advice on Forecast and Response Measures. Floodplain Management Services throughout the Corps offer technical information to communities on procedures that can be followed to establish effective local warning and response systems. Hydrologic, hydraulic, and other engineer data are made readily accessible. Engineers and water resource planners are often available to communities for advice on procedures for installing and operating warning and response systems.

Baltimore and Wilmington Districts have active programs of instructing businesses and communities on specific actions that would be most effective in reducing flood damages and saving lives. For example, a recent Baltimore District report outlines specifically what Sprout-Waldron Corporation should include in an emergency plan. Wilmington District has provided several companies in Roanoke explicit instructions on what actions should be taken immediately and what might be done during a flood event.

Dam Safety.

1) Inventory and Inspection. Beginning in 1981, the Corps undertook an inventory of 63,000 non-federal dams. 8,639 were

inspected, and recommendations were made for the 2,884 dams that were found to be unsafe.

2) Warning Procedures. Procedures for warning and evacuation in case of dam failure have been put in place at all of the Corps permanent storage reservoirs.

3) Dam Safety and Risk Analysis Research. The research in the dam safety/risk analysis program has great potential application to warning and preparedness planning. One of the primary objectives of the research was to evaluate the effectiveness of warning and evacuation plans and dam failure consequences under these plans. This entailed the determination of two key decision variables: warning time and evacuation time. These critical times would then be factored into a set of empirically derived equations which would provide an estimate of the "threatened population" and likely "loss of life" given the base "population-at-risk". The primary aim was not to propose or improve warning and evacuation planning; but rather, to present an "ideal model" for a communications and preparedness plan against which the existing plans could be qualitatively assessed in terms of a number of key indicators: disaster experience, internal communication, perceived probability, commonality of assigned tasks, flexibility, clarity of tasks, resources needed in emergencies, communications, legitimacy, resource linkages, and autonomy.

Among the innovations with respect to ascertaining the effectiveness of existing plans was the introduction of an emergency warning "event tree." This simple analytic tool attempts to establish the likelihood that the various components of warning and response communication network will function as planned, providing adequate warning and evacuation time are given.

A complementary part of the research is the use of an evacuation simulation model, which is used to estimate the minimum time needed to evacuate the flood threatened population. The model can be operated under various assumptions about road and bridge closings and traffic congestion to provide more reasonable estimates of evacuation time during high flood stages. Finally, a great deal of effort went into the development of an empirical loss-of-life estimation model. It is based on a sample of nearly 50 documented flood disasters and dam failures. Warning, population-at-risk and degree of population concentration were shown to be the key forecasting determinants of loss-of-life. The reports are now under intensive review.

The Extent of the Corps' Growing Responsibility in the Planning and Design of Warning and Preparedness Systems

How significant is it? According to a recent survey that Lew Smith conducted of district planning offices, it was determined that at least 30 warning and preparedness programs have been initiated as part of continuing authorities or pre-authorization survey reports. There is likely to be Corps involvement in nearly all stages of the process, including planning, design, installation, and cooperation in emergency operation activity. While the operation of the system is a local responsibility, a preparedness system can help the Corps to more efficiently direct its resources to assist local governments.

Our own discussions with district planning people have indicated a very mixed picture. While there are some districts, such as Wilmington, where planners are encouraged to include warning and preparedness factors in any plan that leaves significant residual damages, there are other districts where the direct experience with planning, designing, and evaluating warning and preparedness is very limited.

New York District: Passaic River Study. The Flood Emergency Preparedness System: Passaic River Basin report was the most detailed study undertaken by the Corps for the planning and design of a warning and preparedness system. This Section 205 project, which was recently approved for implementation by Assistant Secretary of the Army, Robert K. Dawson, is a landmark for several reasons:

1) The study consisted of a very comprehensive look at the existing warning system and the response system. Alternatives were considered to determine the likely improvements in warning lead time and effective response. The evaluation methodology was developed after a thorough review of flood warning evaluation literature.

2) The recommended plan is ambitious. The plan consisted of extensive automatic rain and stream gauge monitoring and automatic report networks. There was an extensive communications system for delivering warnings. Self-help response programs are recommended that will be supplemented by training and practice for community officials and volunteers. Provisions are made for continued public information and intergovernmental coordination.

3) The Passaic System shows that a warning and preparedness system can be designed and implemented as a single component. The system will do a great deal to reduce the likelihood of major damages and deaths from flooding at least until structural measures are in place. Even if there were no other measures to

be implemented the warning and preparedness system would still be highly desireable.

Mobile District, Village Creek. Mobile District has completed the design of at least four flood major flood warning and preparedness programs. Of these, Village Creek has progressed about the farthest. Village Creek runs through the City of Birmingham, Alabama and presently subjects Birmingham to an average annual expected flood loss of $5.5 million per year.

The flood warning and preparedness plan for Village Creek supplements a broad array of other measures including bank shaping and clearing, enlarged natural and concrete-lined channels, and permanent relocation of some of the structures, subject to the heaviest flood risk. The warning plan is complete system of gauges, communications equipment, data collection and processing, and forecasting software. The warning system is estimated to have annual costs of only $10,000 and is justified on the basis that even one percent reduction in the $1.6 million annual residual damages with project would more than offset the costs.

In addition to the details of the forecasting system, which Mobile District would install, the Village Creek project report gives details of the responsibility of every agency involved in emergency preparedness actions.

Wilmington District. Roanoke Virginia has a tremendous need for flood warning. There were 800 businesses flooded in 1985. Because of the $200,000 limit on flood insurance coverage, most of the losses were uninsured. After the flood, many companies had their insurance canceled. The recently completed flood control plan for structural measures leaves considerable residual damage. Roanoke needs flood warning and preparedness. The plan for structural measures is supplemented with a plan for warning and preparedness measures. Structural measures include an increase in channel capacity for 10 miles of the Roanoke River and 1 1/4 miles of levee and flood wall. The plan includes the installation of 11 stream gauges, 12 rain gauges, and a control center with an alarm system. Estimated first cost for the flood warning element were $304,000, of which $61,000 would be Non-Federal costs. Local interests would also be responsible for $17,700 in annual replacement costs and $8,020 in operation and maintenance costs.

The Wilmington District took a conservative approach to the economic analysis of the flood warning system. Benefits were only ascribed to moving a minor portion of the contents that would still be subject to flooding damage after structural works are in place. The flood warning element still had a 1.57 to 1 benefit-cost ratio. Most importantly, the warning plan will give residents and business the opportunity to significantly reduce the substantial residual damages ($2 million annually or 1/2 of the expected damages for without-project conditions) that will likely remain even after the structural measures are in place.

It is now the policy in Wilmington District that flood warning be included in any recommended plan whenever there is any significant residual damage.

St. Paul District. The State of Minnesota has directed every community in the state to develop an emergency action plan. The St. Paul District has become involved in several of these plans, including Stillwater and East Grand Forks.

The St. Paul District has completed a plan for Gasman-Coulee, which includes the installation of precipitation and stream gauges, telemetry, a computer forecast center, and an alarm center.

St. Louis District. The St. Louis District has included a flood warning system in their plans for the Lower Meramec River. The Meramec is a small river that runs through the south and western portions of the St. Louis metropolitan area. The Meramec is an area for which warning and preparedness has enormous potential for damage reduction. Lead times will range from 6 to 12 hours, which would give residents and businesses substantially more time than they already have for moving valuables, sealing openings, and evacuating. The District plans to install a portion of the satellite receiving equipment, gauging information telemetry, and other equipment called for in the plan. A post-disaster survey after the December, 1982 flood found encouraging, but very inconsistent reaction to the warnings that were issued. It was assumed that a more accurate and timely forecasts, with an expanded warning network will lead to at least a 5% reduction in damages. Right now, the district's problem is in convincing the sponsor that the warning system will be worth the $20,000 to $30,000 annual commitment to keep the system operating.

Impetus for Broader Responsibility

National Weather Service Invitation. Four years ago Richard Carnahan, the National Weather Service's Chief of Weather and Flood Warning Coordination Staff invited the Corps to take a more active role in warning and preparedness. Carnahan said that the Corps could be particularly useful in:

1. The Corps' experience in cost-benefit analysis can be used to devise a methodology for estimating the benefits of warning systems.

2. The Corps in cooperation with communities and the Weather Service can design and install warning and preparedness systems.

3. The Corps can devise a program for the continued monitoring of potential dam leaks and cracks.

Communities in Need of Service. Of the 20,000 communities with flood hazards, only 3,000 of the communities receive NWS site-specific forecasts. Many of the communities with site-specific forecasts do not have adequate response plans. Highly sophisticated warning systems would not be cost effective for much of the United States. Most of the unforecasted 17,000 communities are small and the additional benefits would not be worth the expense. Still, bringing communities up what they should have available is a massive job that requires multi-agency cooperation.

Corps of Engineer Resources. What can the Corps offer to communities that would not otherwise be available to them? The Corps, through its many district offices, provides an extensive base of engineers and planners trained in solving flood problems. No other organization has as vast a base of data and analytic tools that could be useful in this effort.

Impediments to Greater Involvement

Lack of Adminstration Policy Directive. There has been a lack of clear direction to incorporate warning and preparedness. There is no regulation that explicitly commits districts to consider warning and preparedness. ER 1105-2-200, "Project Purpose Planning Guidance," gives a rather weak view of the Corp's responsibility for warning and preparedness:

"Other than to provide technical assistance and planning guidance to appropriate governmental levels, Corps participation in implementation of nonstructural measures is generally limited to permanent evacuation and relocation, flood proofing, and provision of equipment devoted exclusively to flood warning systems or temporary evacuation when flood warning or temporary evacuation are elements of an overall flood damage reduction plan."

The regulations do not adequately reflect what has been administration policy since the House Document 465 was issued in 1966 to place a greater emphasis on nonstructural measures. The regulations do not explicitly say to the districts that they can go out and plan, design, and install warning and preparedness systems.

Lack of a Documented Track Record of Flood Warning and Preparedness Effectiveness. The primary researchers in evaluating warning and preparedness, such as Krzysztofowicz and Davis and Penning-Rowsell, complain about the paucity of data which might be used to estimate flood damages, loss of life, and injury, without and with various types of warning and preparedness systems. There will be a good deal of conjecture in the design of warning and preparedness systems until a good deal is done to document how warning and preparedness systems perform and the factors that promote a systems success or failure are isolated. Within the Corps, there are few, if any warning systems that the Corps has planned and designed that have thus far been implemented, let alone tested.

Lack of Evaluation Procedures. There has been a lack of any standard procedure for evaluating the benefits and costs of FW&P systems. Several districts have come a long way to overcoming this problem, through a very conscientious effort of blending previous evaluation experience with review of literature and case studies. A major part of this effort has been to document enough areas of success to demonstrate that even with the considerable uncertainty as the performance of the system, evaluators can still have a good degree of confidence in the economic justification.

No Specific Degree of Protection. Flood warning measures are viewed as limited solutions which leave considerable flooding problems. This criticism has a good deal of merit. FW&P can never be viewed as a total solution to a community's flooding problem. Significant residual damages will remain. So, unless the community is resolved to accepting a continual risk, FW&P should be thought of as an interim or supplemental measure.

Lack of Planning and Design Experience Specific to FW&P. While the Corps has a very rich experience in dealing with nearly every component of a warning and preparedness system, some districts still lack direct experience at planning and designing entire systems. The resources available in a district may be scattered between planning, hydrology, and emergency operations.

The expertise in the greatest need of development is the capability to work with communities to design communications and emergency response systems.

Uncertain Cost-Sharing. The same confusing atmosphere on project financing that has delayed the authorization and implementation of other water projects has delayed the implementation of FW&P systems. This ambiguity should be greatly diminished by the 1986 Water Resources Development Act.

Enhancing Community Warning and Preparedness Systems

The following activities could be taken by the Corps in cooperation with other agencies to enhance community warning and preparedness systems:

Development of Economic Evaluation Procedures. These procedures can be used for determining the make-up of a warning and preparedness programs as part of an optimal mix of flood alleviation procedures. Included in those procedures should be ways for handling the following issues:

1) There is a high degree of uncertainty associated with several important variables. This is largely because of the severe lack of empirical data on the performance of warning and preparedness systems. It will be particularly important to determine the effect of various forecasting components on the accuracy and lead time, the minimum amount of lead time required for safe evacuation and various damage prevention actions, the extent that individuals are likely to respond and respond effectively to warnings, and the private as well as the public costs of response.

2) No specific degree of protection can be associated with warning and preparedness schemes.

3) Public safety considerations are a major justification for warning and preparedness which can not be easily incorporated into the benefit-cost analysis.

Compilation and Maintenance of a Detailed Inventory of Flood Warning and Preparedness Systems. This information would be critical to any programmatic review of flood warning and preparedness systems and for the evaluation of the effectiveness of system components.

The data base for implemented projects would include: 1) a description of the original problem, 2) a description of the elements of the proposed solution, 3) a summary of the estimated costs and benefits of the proposed solution, 4) a description of the project as it was actually implemented, including a recognition of what is different from the proposed plan and why, 5) detailed post-implementation studies for selected projects and rough estimates for other projects, 6) community and individual response to these projects can also be recorded, and, 7) comments on planning methods used in formulating and evaluating alternatives.

Expanded Interagency Coordination. This can be done through such channels as the Interagency Task Force on Floodplain

Management to determine the efficient and responsive ways for agencies to pool their resources.

Expanded Agency Guidance and Training Opportunities. There should be an expansion in the guidance and training opportunities for district on how to design, evaluate, and help maintain warning and preparedness systems.

Conclusions

The Corps has taken on a major role in warning and preparedness that needs to be incorporated formally into agency regulations. The capabilities and the mission of the organization should be made apparent to those inside the Corps as well as to other agencies and communities so that the role of the Corps can be legitimized and enhanced.

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PAPER 5

LOCAL FLOOD WARNING SYSTEMS IN SOUTH ATLANTIC DIVISION - A PERSPECTIVE

BY JAMES C. ORSAK [1]

ABSTRACT: The U.S. Army Engineering Division, South Atlantic (SAD), has been focal area for implementing Local Flood Warning Systems (LFWS) for communities in conjunction with comprehensive flood control projects. The Mt. Airy, NC, detail flood protection project has a LFWS to provide warning time for structure closure and project operation. Three flood warning systems are proposed in major cities within SAD with recent historical floods. SAD sees the need for a national policy which defines the Corps role in developing LFWS and for ooperation of the Corps, National Weather Service, state and local government agencies

INTRODUCTION

In recent years flooding along major rivers and creeks within South Atlantic Division (SAD) has become an increasing hazard and a threat to public safety. The flashy characteristics of these streams in densely urban areas also pose a threat to human life and cause extensive property damage. The geographical region in SAD includes the states of North and South Carolina, Georgia, Florida , Alabama some watersheds in Virginia and Mississippi and the Commonwealth of Puerto Rico. This southeastern part of the United States has a high annual rainfall and maximum floods usually occur during the spring season and hurricane season (August - October).

FLOOD THREAT REMAINS

One of the Corps of Engineers (CE) main missions is to reduce flood damages by designing and constructing structural or nonstructural flood control projects. While future flood control improvements - dams, levees, floodwalls, channel modifications, floodproofing or relocations of homes - may reduce damages along these streams, there will continue to be substantial risks for those remaining in the watershed. Many residential properties and industrial developments will remain subject to periodic floods that exceed the design flood selected for the project based on benefits and costs. There could also be a danger to crucial public facilities and to those person utilizing the area on a temporary basis such as motorists crossing bridges or persons using parks in the floodway. Those persons may be aware that any flood hazard exists.

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GENERAL KNOWLEDGE OF FLOOD HAZARDS

For those persons living within the flood-prone areas along flashing streams and for responsible local authorities, knowledge of the stream flooding characteristics is essential for protection of life and property. It is necessary that those persons in the most hazardous locations has some basic understanding of the dangers and that they recognize the need for an operational flood warning and response system. A plan of action, or community response plan, is fundamental since the very best state-of-the-art flood warning system becomes meaningless.

POTENTIAL WARNING TIME

Reaction time or potential warning time (1) - the time between the first measurement or rainfall and the first occurrence flooding - may vary from minute to several hours for streams in the southeast. The warning time will vary with location along the stream and with the distribution and intensity of rainfall. For the most critical events when high intensity rainfall is centered over the basin, the time from beginning of rainfall to peak stage may be less than one hour. If less critical rainfall events occur over a more extended period of time, or when the storm is centered at the headwaters of the basin, the warning time may be substantially longer. If early flood forecasting is taken seriously then there may be several hours to prepare for the peak flood. This situation suggests that local communities should initiate preparations of a response plan when conditions are highly favorable for the occurrence of a flash flood based on the weather forecast by the National Weather Service (NWS). Then it becomes necessary to mobilize and issue flood warnings to save life and property.

MT. AIRY, N.C. STUDY

In March 1983, the CE Wilmington, NC District completed a detail project report entitled, "Flood Damage Reduction Ararat River, Mount Airy, Surry County, N.C." (4). The report recommended an automated flood warning system for Ararat River in conjunction with the Corps flood control project.

Ararat River headwaters are in the Virginia Blue Ridge mountains, with upland elevations of about 2,800 feet, m.s.l. After a short travel of approximately 5 miles, the river waters enter the piedmont plateau at about elevation 1,400. The stream slope than moderates, averaging about 40 feet per mile fall until the Virginia-North Carolina line is reached, a distance of about 7 miles. Between this point and the river confluence with Stewarts Creek, some 10 miles downstream, fall is a fairly uniform 28 feet per mile. The project reach at Mount Airy is located in this section of the river, centered about 5.5 miles downstream from the State lines.

The basin above Mount Airy is roughly wedge shaped, about 12 miles long and averages nearly 6 miles wide. The Piedmont plateau in this region is characterized by hills, narrow ridges, and low knobs. It is largely rural in character, with development within and around Mount Airy representing the only significant urbanized area. Figure 1 shows the Ararat River Basin and the study area. The drainage area above Mt. Airy is 66 square miles; the total drainage area of the basin is about 230 square miles.

In 1979 the most severe flood in the memory of local residents occurred. Floodwaters reached heights of 5 to 6 feet in the industrial facilities near the river. Total damages due to the flood were estimated at more than $11 million in Mount Airy and vicinity. As a result, the greater Mt. Airy was declared a major disaster area.

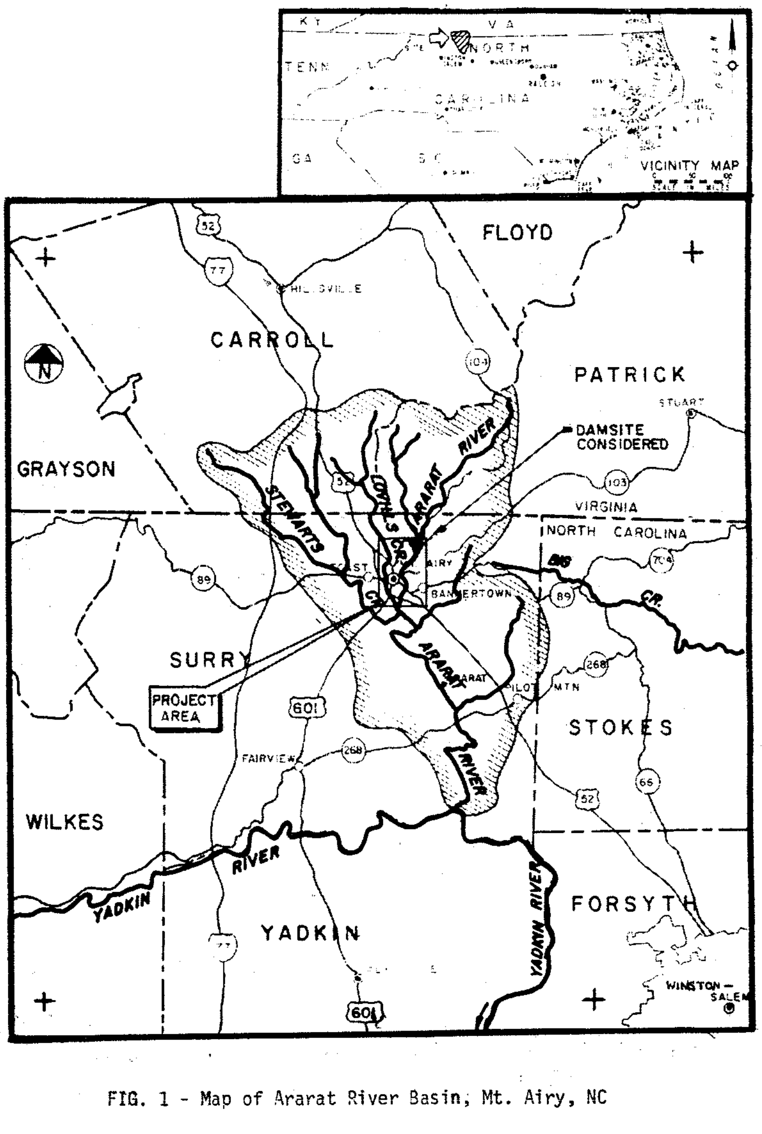

FIG. 1 - Map of Ararat River Basin, Mt. Airy, NC

The CE recommended structural plan for Mt. Airy includes a floodwall/dike 1800 feet long which provides 100-year protection for commercial development and channel improvements, total length 6,700 feet, which provides for residential protection up to the 15-year flood.

FLOOD WARNING SYSTEM FOR MT AIRY.

The nonstructural plan is the installation of the flood warning system for a response plan. The warning system for Ararat River was based upon and fully compatible with the Automated Local Evaluation in Real Time (ALERT) data collection and forecasting system originally developed by the U.S. National Weather Service California/Nevada River Forecast Center in Sacramento, CA (2).

Basically the automated flood warning for Mt. Airy consisted of the following components:

1. Auto precipitation and stream gages.

2. A communication system.

3. Automated data collection and processing equipment.

4. Flood forecast software.

These components will be incorporated into a plan of action to be utilized by the responsible authorities. Also, the warning system will forecast a potential warning time to place stop-logs at a railroad closure structure connected with the floodwall. This is an integral part of the flood protection plan. The total cost of the flood warning system is about $60,000, with the CE share being 80% and the local sponsor paying 20%. The flood warning system will provide the following benefits - potential warning time of 3 to 5 hours before overbank flooding begins and 7 to 9 hours warning time for stop-log closure. The actual placement of stop-logs will be conducted as a "real time" operation, the system will be activated and the local sponsor will send personnel to conduct a test run to close the structure.

The NWS and the City of Mt. Airy signed a Memorandum of Understanding (MOU) for the purpose of defining a mutual assistance program designed to develop an enhanced Flash/Flood System for Ararat River. The CE did not enter into this agreement and provided only the equipment as described in the Scope of Work. The Scope of Work also defined the installation services of the system and was issued to perspective bidders or vendors of ALERT real time data telemetry instruments. Since this was the first flood warning system being installed within SAD, both the NWS and the CE did not have a clear vision of each agencies involvement in developing the warning system.

LESSONS LEARNED FROM MT. AIRY STUDY

The CE and NWS have concluded after the ALERT system was installed and operational for Mt. Airy that the following items should be resolved in future studies:

1. From the inception of the project there was a problem of ever-changing computer equipment and software models due to rapid change in the state-of-the art computer ALERT systems. This required several revisions of the Scope of Work and changing equipment costs which delayed bidding.

2. The CE and NWS should have signed a MOU to define the technical assistance each agency should provide.

3. The local community did not have a clear perception of the CE role in developing the software model.

4. Providing the software flood forecasting model was originally planned by the NWS, but when the LFWS was finally approved by SAD in the detail project report, the NWS could not provide ongoing software support. This required contracting with vendors of ALERT equipment, thereby increasing the LFWS cost. Recommend that all software support services be provided by the selected vendors and included in the cost estimate.

5. The operation and maintenance (O&M) cost was underestimated for the ALERT system. Mt. Airy O&M will be about $4,000 per year which is the local community responsibility.

FUTURE STUDIES WITHIN SAD

The floods of December 1983 in Birmingham, Alabama caused extensive property damage and one death. The NWS had reported 9.25 inches of rainfall from 8 pm Friday to 8 pm Saturday which was a record rainfall for a 24-hour period. Flooding along Village Creek, a stream just west of downtown Birmingham, damaged 300-500 homes. As a result the Mobile District CE have completed a report for Village Creek (3) recommending basically a nonstructural plan which includes evacuating 627 structures and enlarging 2.2 miles of the stream channel. An ALERT system is proposed for this project for emergency evacuation of persons and property remaining in the flood plain. The nonstructural plan provides protection up to the 10-year flood. The estimated cost of LFWS is about $106,000.

In November 1985 a low pressure system moved northeastward out of the Gulf of Mexico across Virginia bringing record-setting rainfall to Roanoke Valley, Virginia. Up to 18 inches of precipitation were reported with record breaking flooding occurring in the headwaters of Roanoke, James and Potomac River Basins. River levels exceeded crests previously established during the passage of tropical storm Camille (1969). At Roanoke, the Roanoke River rose 7 feet in one hour between 11 am and noon on November 4th, and nearly 18 feet in about 6 hours. Had this event taken place during the nighttime hours casualties would have been much higher. There were ten deaths reported in Roanoke Valley, and total losses in Virginia approached $750 million. The flood was estimated to be a 130-year frequency event.

The Wilmington District CE has completed a report (5) recommending a structural plan for Roanoke River consisting of 10 miles of channel improvements and 1.5 miles of dikes and floodwalls. However, to provide early detection of flood-producing rainfall and rising river levels, an ALERT system is being designed. The system would also provide automated rainfall gages at the headwaters of Roanoke River where few gages exist. The cost of the ALERT system is about $300,000. This cost is higher than other studies previously discussed because the drainage area is about 400 square miles and formed by main headwaters tributaries, the South Fork and North Fork Roanoke Rivers.

The NWS is also expanding its Integrated Flood Observing and Warning System (IFOWS) in the Roanoke Basin and this may reduce the equipment cost. The NWS will discuss IFOWS during this seminar.

Other flood warning systems that are in the design stage will be installed for Sowashee Creek project in Meridian, Mississippi and Tallahaha Creek in Laurel, MS. These LWFS will be cost shared with the local sponsor.

GENERAL MEMORANDUM OF UNDERSTANDING (GMOU)

Since SAD realized that its Districts were embarking on numerous projects that recommended flood warning systems, it was time for a cooperative agreement with the NWS to expedite these studies. Therefore SAD and the NWS River Forecast Center in Atlanta met in July 86 to develop a GMOU that would define the involvement of each agency in providing technical assistance in implementing LFWS. The nature of the agreement and the technical assistance each agency would provide include the following:

1. Nature of Agreement

A Local Flood Warning System (LFWS) for communities could be implemented in conjunction with a comprehensive flood control project developed by the CE. The LFWS utilizes state-of-the-art techniques that can be incorporated into an operational flood warning and response plan. The overall concept calls for CE and NWS cooperation. Therefore upon knowledge of a proposed LFWS in any flood control project, the CE will contact the NWS for their assistance. Likewise when the NWS is notified of a possible LFWS by any agency outside the CE, they will notify the CE.

2. Involvement of the National Weather Service

The NWS involvement will consist primarily of technical assistance to the CE and the local community from the inception until the LFWS is totally operational. This assistance is necessarily contingent upon availability of Resources within the NWS. This assistance would include:

a. Initial layout of river/rain gage locations for maximum protection.

b. Coordinate radio frequency usage, obtain the hold necessary FCC radio frequency authorization and licenses for those radio units necessary for incorporation into a LFWS.

c. Cooperate with local sponsor and CE to identify the need for specific equipment for the warning system.

d. Provide CE and local sponsor cost estimates of proposed LFWS equipment and lists of vendors offering this equipment. (Note: The NWS has an existing list of vendors that provide ALERT equipment in accordance with NWS standards).

e. Assist in the installation of the base station and remote gages.

f. Training of local users in the operation and maintenance of the system hardware and the interpretation of the system output.

g. Prepare a MOU with the CE and local sponsor which define the responsibilities of each in the establishment of a LFWS.

h. Work with the CE and local sponsor to develop a response plan for the community for flood emergencies.

i. Continued technical expertise when called upon.

3. Involvement of Corps of Engineers

The CE should continue to maintain its close association and cooperation with the NWS and the local sponsor. The Corps involvement in the LFWS is essential to ensure the long-term integrity of the flood warning system for local communities and to protect the Federal investment. The CE will provide technical assistance for planning and installation of the LFWS in consultation with the NWS and the local sponsor. The CE will provide assistance for the following items:

a. Prepare a MOU with the NWS and local sponsor which define the responsibilities of each agency in the establishment of a LFWS.

b. Assist the NWS in the initial layout of river/rain gage location.

c. Assist in developing the hydrologic observation network.

d. Work with local sponsor in the selection of vendors that maintains NWS local flood warning equipment standards.

e. Assist the NWS in training personnel on the operation of the LFWS as it relates to the project function and response plan.

f. Assure that the local sponsor maintains and operates the LFWS for the life of the project.

g. Works with the NWS and local sponsor to develop a response plan.

h. Provide funding, as needed, to NWS to cover labor and travel costs involved in development of the LFWS.

3. Final Agreement:

Where upon this general agreement defines the preliminary working relationship between the CE and NWS for planning and installation of a LFWS, a final MOU between the agencies should be implemented for site specific studies. It is expected that changes will be made to this general memorandum when it is signed by the CE and NWS.

RECOMMENDATION

The GMOU was submitted as a draft to the CE Office of the Chief of Engineers in Washington, D.C. for their consideration and action. SAD's letter to the Chief recommended that this GMOU be adopted at the headquarters level, but no national GMOU has been established at this time.

CONCLUSIONS

Where major flood hazards exist, local communities should recognize their responsibility for public safety and the potential benefits from LFWS. The ALERT system has proven to be very cost effective for reducing flood damages and saving lives. Since the CE is required to look at LFWS with their future flood control projects, it is essential that a national MOU be developed which defines the CE role in developing LFWS and for overall cooperation of the CE, NWS, State and local Government agencies. All agencies should strive to promote local warning and response systems to mitigate flood losses.

APPENDIX - REFERENCES

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State-of-the-Art Flood Forecasting Technology

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I. Introduction -

The following material is a collection of notes regarding the current state-of-the-art of flood forecasting in the U.S. This material is not intended to be an authoritative statement on this topic, but is rather a basis for beginning to understand and discuss where this technology is today. The material is primarily derived from a number of informal communications with individuals in various offices working in this area, as well as, reference to selected literature.

For the purposes of this paper the term "State-of-the-art" is interpreted to mean that which is currently in operational use today. This is in distinction to its use in research circles where the term often means, that which is on the cutting edge of technology, but usually not yet in general use.

The main responsibility for flood forecasting in the U.S. is the mission of the National Weather Service (NWS). The NWS prepares flood forecasts for public dissemination. Several other federal, state, county, city, and private organizations prepare themselves, or cooperate with the NWS, in preparing forecasts for certain other specific purposes.

The Corps of Engineers (COE), as an agency responsible for the operation of more than 600 water resource flood control projects across the country, must utilize forecasts in determining project releases. In that project releases affect river flows and hence forecasts, there are many interactions between the NWS and COE on a daily basis. This paper will confine itself to the procedures used within these two agencies (ie. NWS and COE).

II. National Weather Service Procedures

There are three primary methods in use by the NWS for flood forecasting. The first and most widely used method is based on an Antecedent Precipitation Index (API). The second method is the Streamflow Synthesis and Reservoir Regulation (SSARR) model. The third method is the Sacramento Soil Moisture Accounting (SSMA) model.

A) Antecedent Precipitation Index (API)

The API is a running index up, dated daily, that reflects the current moisture level of the area. The API is increased by precipitation and decreased by a seasonally dependent factor. The API for a given day is then used in a rainfall-runoff relationship along with the week of the year, the storm rainfall depth, and the storm duration. The resulting storm runoff is then applied to the appropriate unit hydrograph for the area to generate sub-basin runoff.

Where larger areas are being represented the resulting runoff from each sub-basin is routed and combined with runoff from adjoining sub-basins. The resulting flows can be used with gage rating tables to produce river stage hydrographs. The time interval of the precipitation used in the analysis is most commonly 6-hours. This data is usually received from a variety of sources and is commonly reviewed and interpreted manually before use in the method.

An important part of any method is the allowance for correction of the predicted results as observed streamflow becomes available. In the API method several opportunities exist to allow observed data to feedback into the predicted results. This correction may alter the computation of the API, or alter the storm runoff, depending on the assessment of the hydrologist.

The API method appears to be used for about 70 percent of all forecasts developed by the NWS. The method makes use of all available precipitation information, allows correction, is easily understood, and produces a full hydrograph as the forecast.

B) Streamflow Synthesis and Reservoir Regulation (SSARR)

The SSARR model is the product of a joint effort of the NWS and the COE. This model is used by each of the respective agencies in the Pacific Northwest to forecast flows and regulate projects in the Columbia River and adjoining areas. This model uses a continuous moisture accounting method to determine the amount of precipitation and snowmelt that will become runoff.

The volume of runoff is determined separately for up to three phases of runoff that reflect direct runoff, interflow, and baseflow. Each of these runoff components may be routed through a cascade of linear reservoirs (equivalent to a unit hydrograph) to produce the time distribution of total streamflow.

The SSARR model is usually run for flood forecasting using precipitation and temperature data supplied at 6-hour intervals. As with other methods this data is usually manually screened before use with the model. The SSARR model has a capability of using a recent observed flow as a basis to update the internal moisture algorithm when the computed results deviate from measured streamflow.

The SSARR model is the only method used in the Pacific Northwest. Thus, it is used to develop about 10 percent of the forecasts issued by the NWS. It is designed to meet the rainfall and snowmelt runoff regimes there. It is a simplified continuous method the allows easy feedback to correct the model results.

C) Sacramento Soil Moisture Accounting (SSMA)

The SSMA model is a comprehensive soil moisture model intended to represent the movement of water in the upper portion of the soil strata. The method was developed in the California-Nevada River Forecast Center in Sacramento. It has been incorporated into the National Weather Service River Forecast System (NWSRFS).

The SSMA method uses precipitation input and produces estimates of the volume in each of four runoff components. The moisture that enters the soil surface is then redistributed through a series of accounting algorithms. Water leaves the system through runoff, evapotranspiration, or non-channel baseflow.

The runoff, thus produced, may then be distributed in time through a histogram and routing operation. The SSMA method itself produces only runoff from a headwater basin. When connected to a combining and routing model, as implemented in NWSRFS, runoff from larger basins may be simulated.

When model results are not in acceptable agreement with measured streamflow, the runoff may be adjusted to more closely conform to observed conditions. It may be also appropri-ate to alter the input precipitation amounts to force model agreement, but such action would also have a long term runoff effect.

The SSMA method incorporated in the NWSRFS is used for developing about 20 percent of the NWS forecasts. The SSMA method is also used as a forecast technique in some local flood warning systems. The ALERT local flood warning systems use this method for producing runoff from headwater basins.

D) Flood Advisory Tables

A fourth technique used for rapid peak stage forecasts uses moisture indexes produced by the API or SSMA methods. This technique relies on a Flood Advisory Table of pre-computed flood stages for various antecedent conditions and average basin rainfall amounts. This technique is provided for WSO, and small communities that need a simple quick method to produce an estimate of flood peak. The RFC provides current values of the Basin Index, reflecting antecedent conditions. The local user can then access local precipitation in the area, enter the Flood Advisory Table with the current Basin Index, and determine a flood peak estimate.

III. Corps of Engineers Procedures

The operation of a Corps water control project is the responsibility of the COE District/Division in which the project resides. The techniques necessary to perform the operation are chosen based on the type of structure, size of structure, relationship to other projects in the basin, and other local considerations.

In some cases the forecast provided by the NWS to meet its public warning mission is also used by the COE in the operation of a water resource project. In other cases it is necessary for the responsible COE office to develop supplemental forecasts. This is often required where the NWS forecast locations do not include specific project inflow points, or critical control points downstream of the project. Often it is necessary to evaluate the effects of several possible future forecast scenarios, before determining a final project release.

A) SSARR

The SSARR model is used by the North Pacific Division (NPD) COE office in its regulation of the Columbia River, Williamette River, and associated basins. This model has been outlined previously.

B) HEC1-F

The Hydrologic Engineering Center (HEC) has developed a system of software used by several COE offices for the development of flood forecasts. The forecast technique uses an initial and uniform lossrate, with the runoff applied to a unit hydrograph to produce a sub-basin forecast. The results for each sub-basin may be combined and routed to develop runoff from larger basins. This technique uses the observed flow in the river system to set the proper lossrate variables necessary to reproduce a given event.

The model can also make minor adjustments to the shape of the unit hydrograph during the event to correct for slight hydrograph timing abnormalities. The feedback to refine the model coefficients is limited to only headwater basins, and then only if several data validity criteria are met. Model coefficients used for non-headwater basins must be set by the forecaster if other than the fitted values are to be used.

Addition feedback from observed flows are made as the model combines and routs down through the river system. In this step the observed flows are preserved up to the current time and a blend is made from the observed flow to the forecast flow over a specified number of future flow periods. This procedure assumes that observed flows are always more reliable than model derived flows and should be used where ever possible.

The HEC1-F model is currently being used for forecasting in at least 7 COE districts. Many other COE district offices use similar rainfall-runoff forecast techniques as indicated here that have been developed locally.

IV. Local Flood Warning Systems

The local flood warning - response system (LFWRS) may be used in a range of possible configurations. This may be from just a simple data gathering installation, to a large basin system producing forecasts from rainfall, and snowmelt runoff.

Current methodology available for flood forecasting in LFWRS's roughly parallel that available in the NWS. LFWRS's may be imple-mented to use the SSMA procedures to produce runoff from head-water basins. ALERT systems implemented through the NWS often are installed with this model. Extensions to the NWS ALERT systems allow the modeling of more complex basins by the addition of combining and routing techniques. In addition, when forecasts are produced several future precipitation alternatives may be evaluated.

Other possible LFWRS implementations would allow the production of forecasts based of the API and Flood Advisory Table methods. Still other techniques combine several factors relating to the degree of flood severity and produce a composite rating displayed to the user. This rating can be used to trigger appropriate local action.

OVERVIEW OF LOCAL FLOOD PREPAREDNESS PLANS

By H. James Owen[1]

So far as is known to the author, there has been no systematic effort to collect and/or evaluate local flood preparedness plans. This prevents presenting and documenting any firm conclusions about what common characteristics these plans might have or even describing their availability with any accuracy. Also, so far as is known to the author, there has been no systematic investigation of the performance of local flood preparedness plans that do exist and have been tested in a flood. This prevents arriving at any factually supported conclusions about the types and amounts of their benefits, insights into what works or doesn't work, problems that have been encountered, identification of strong points worthy of emulation by others or learning other valuable information. The same general lack of knowledge exists with respect to the degree and effectiveness of coordination between the flood detection, warning and preparedness elements of local programs, and with respect to such things as techniques of financing and implementing flood preparedness plans or carrying out the associated public information programs. This dearth of information about what appears to be a potentially important measure for reducing flood losses is reflected in the lack of explicit criteria for what ought to be considered and included in a flood preparedness plan, in the lack of well documented and well publicized prototypes, and in the lack of authoritative guidance for local officials and planners on how to go about development of flood preparedness plans. The fact that there is so little information available concerning flood preparedness plans suggests there has not been much interest in such plans on the part of local, state and federal governments.

Observations on Existing Preparedness Plans

In the absence of supporting factual information, the following observations about local flood preparedness programs are based on the author's familiarity with situations in a few areas, discussions with some local program managers and limited data collection:

- While flood warnings have no intrinsic value of their own and it is the response to warnings that saves lives and reduces economic losses, most attention has focused on the flood detection element of local programs and little effort or funding has gone into preparedness planning.

- Many communities, including some of those with flood detection systems of one type or another, either do not have a flood preparedness plan, or have a flood preparedness plan that is so vague or limited that it exists only in name for all practical purposes. Where flood preparedness plans do exist, they tend to deal only with evacuation and give little or no attention to reducing damages or other flood-related economic costs.

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- Existing flood preparedness plans tend to be one of two types. Either they consist mainly of assignments of responsibility or they consist largely of a list indicating the parties who should be notified at various stream elevations. In this latter type of plan, the stream elevation on which action is to be based is usually the actually observed stream elevation in the area rather than a predicted future stream level such as might be provided through a flood detection system. Few of the existing plans provide any type of complete action document by describing tasks to be done, assigning responsibility, spelling out the resources to be used for each task and otherwise defining the action to be taken.

- In some cases, a flood preparedness plan of sorts exists but is unwritten. Such plans are more likely to be said to exist by emergency services personnel in areas that have been flooded in the recent past and the plans consist generally of the memory of what was done in that instance without much further analysis. Such plans are not usually accompanied by drills, training sessions or other activities that would tend to institutionalize the plan and pass knowledge of it on to those who might succeed the person currently responsible for preparedness planning.

- Among communities having both a flood detection system and a flood preparedness plan, some had a preparedness plan prior to developing the flood detection system while others developed the preparedness plan after the flood detection system was implemented. There are few, if any, instances in which the development of a flood detection system, warning arrangements and preparedness plan were undertaken simultaneously in one comprehensive effort.

- The flood preparedness plans that exist generally lack the type of analytical foundation necessary to ensure their efficiency or protect against major shortcomings in their execution. For example, plans are seldom based on an analysis of the resources likely to be available, the time potentially available for carrying out emergency actions, or explicit consideration of the relative benefits of devoting available resources to one task versus another.

- Existing flood preparedness plans tend to simplify the potential flood situations that could occur. Few plans make provisions for alternative courses of action depending on the warning time available or the expected severity of flooding other than enlarging the area of evacuation as appears necessary and/or notifying additional parties.

- Flood detection systems and flood preparedness plans are sometimes the responsibility of the same agency and sometimes of different agencies. Where the responsibilities are divided, coordination tends to be weak. It appears that some local operators of flood detection systems view coordination as only requiring that the agency in charge of the preparedness plan is aware that the flood detection system exists and that flood predictions be made available to them as they become available.

Impediments to Flood Preparedness Planning. As suggested by the foregoing, the preparation of flood preparedness plans lags behind that of flood detection systems and the preparedness plans that do exist tend to be poor. There appear to be at least four major reasons for this situation, namely:

- Lack of precedents, examples or similar activities that could provide a basis for the expedited development of flood preparedness plans through analogy to or modification of already existing plans for other types of emergencies.

- Lack of awareness of the potential benefits of comprehensive and fully detailed flood preparedness plans.

- Lack of federal interest and leadership in flood preparedness planning.

- Lack of appreciation of the need for preparedness planning as a basis for the development of flood detection systems.

Lack of Precedents and Examples. Our present capability to plan, design and implement the several elements of local flood detection and preparedness programs is uneven with the state of the art being considerably further ahead with respect to flood detection and warning arrangements than for preparedness planning. This is at least partly due to the greater availability of experience in fields closely related to flood detection and warning which can be more or less directly applied. Equipment and procedures for flood detection, for example, have benefited from a long history of hydrologic measurement and analysis by the National Weather Service, U.S. Geological Survey, Army Corps of Engineers and others. Since the mid-70's, the National Weather Service has put considerable money and effort into applying this experience in the development of flash flood alarms, observer networks, and automated monitoring networks.

Likewise, arrangements for disseminating flood warnings have benefited from their similarity to arrangements for mass warning for civil defense and other purposes and a wide variety of equipment is available for disseminating warnings as well as detailed procedures for designing specific warning systems. Many communities already have extensive mass warning systems, an emergency broadcast system and other provisions for warning as a result of federal leadership and cost sharing. In addition, research into the sociological aspects of creating and delivering warning messages has received considerable funding.

Comparable types of experience that could be easily adapted to the special case of flood preparedness planning do not exist, due in large part to the significant differences between floods and other hazards. These differences limit the extent to which models for local flood preparedness planning can be derived through analogy to preparedness plans for other purposes. Some similarities exist between these different types of plans, especially in areas such as the chain of command, coordination, and communications. However, the specific tasks to be undertaken differ greatly from hazard to hazard depending on the speed of onset of the disaster agent, the possible length of warning time, the potential for mitigating losses through prompt action, and other characteristics of the hazard. Differences between hazards may also dictate different evacuation routes and destinations, different needs for personnel and other resources, and different agency roles. These differences limit the usefulness of "all hazard plans" or plans for other hazards as models for flood preparedness planning.

Its perhaps worth note that flood preparedness planning differs from most other types of disaster planning in that more warning of the impending event is usually available, allowing planning to consider mitigation of losses or even, in some cases, avoidance of the disaster. This is not generally the case with earthquakes, explosion, aircraft disasters, and other causal agents for which preparedness plans are developed.

In addition, preparedness plans for riverine flooding also differ in some significant ways from plans for other potential emergencies for which some advance warning is available. For example, even though the length of warning time may be greater for hurricanes, a well-designed flood detection system enables predicting the magnitude, severity and location affected by riverine floods more accurately than can be done for hurricanes. This combination of smaller areas and numbers of people at risk and the greater specificity of prediction makes it worthwhile to develop emergency plans for riverine flooding in considerably greater detail than plans for responding to hurricanes. Preparedness pkanning for riverine flooding also differs in that it can and, in most cases should, incorporate actions for reduction of damages and other economic costs whereas preparedness planning for hurricanes generally is limited to arrangements for evacuating and sheltering the large numbers of people affected by the event.

The development of flood preparedness plans by analogy to or by modification of other types of preparedness plans is also limited by the large variability in the possible magnitude and other circumstances of floods as well as the matter of possible interactions between the preparedness actions and other actions to mitigate or avoid the hazard such as operation of levees and flood fighting. These factors, along with each community's unique geographic and hydrologic setting give rise to the need for highly individualized development of preparedness plans and this makes them both complex and time consuming to prepare.

Lack of Awareness of Benefits. It might be expected that the complexity and cost of flood preparedness planning would discourage the development of plans in communities with only a modest flood problem. However, if complexity and cost were the only inhibiting factors, those communities with a long flood history which have searched for some solution to recurring flood losses would have proceeded on their own to develop detailed and effective flood preparedness plans based on their own experience. But, this does not appear to be the case. The absence of well-developed plans in those kinds of communities suggests that the economic and other benefits of a well developed flood preparedness plan are not clearly known and that this may be a significant reason why the conceptual and practical development of flood preparedness plans has lagged.

While it is clear that detecting an impending flood and warning people is vital to reducing losses, the economic benefit of a formal plan to guide public and private response to the emergency is less apparent. In those cases in which lifesaving is the primary incentive for a warning system, for example, the availability of a timely warning plus the capability of a community's emergency agencies to deal extemporaneously with evacuation and rescue is likely to go far toward reducing deaths, particularly in small floods and/or in areas where topography provides easy access to safe areas. Somewhat similarly, some extemporaneous action to reduce economic losses can be expected on the basis of just a warning. The fact that some or even considerable benefits can be obtained by extemporaneous action may lead some community officials to believe that the additional benefits of having a specific plan for response may not be sufficient to justify the cost of its preparation and maintenance. This may be especially so in the case of direct damages to private property since the property damage reduction element of a flood preparedness plan is likely to focus more on public property than on private property. This kind of shallow analysis may suggest to some local officials that the most efficient local program is one that emphasizes flood detection and warning and puts little effort into preparedness planning.

Lack of Federal Interest and Leadership. Notwithstanding the foregoing, the chief reason why flood preparedness planning has lagged is the low level of federal interest in the subject. For many years, leadership of local preparedness planning, including preparedness planning for floods, was primarily the responsibility of the Defense Civil Preparedness Agency. However, that agency chose to limit its interest almost exclusively to war-related preparedness planning and only addressed other types of preparedness planning through the concept of a generalized "all hazards plan". The Federal Disaster Assistance Administration also had a potential role in local flood preparedness planning but focused its efforts on post-disaster recovery rather than on mitigation of losses through preparedness planning.

The void in effective federal leadership in flood preparedness planning was filled to an extent in the mid-70's by the National Weather Service as a part of their effort to stimulate installation of local flood detection systems. While the agency's authority in the area was not very strong and the time and effort that could be devoted to the subject was limited, a small amount of progress was being made. The National Weather Service's small effort in this area was suddenly curtailed by the organization of the Federal Emergency Management Agency in which the responsibility for federal leadership of the preparedness planning portion of local flood detection and preparedness programs was put with the new agency.

Since its organization, however, the Federal Emergency Management Agency's effort to pursue this responsibility has been limited largely to the inclusion in recent post-flood mitigation team reports of recommendations that local flood warning and preparedness programs should be implemented. To date, the agency has not placed any priority on providing technical assistance to communities that express an interest in such programs nor has it provided any financial incentives such as through rate setting for the National Flood Insurance Program to encourage broad nationwide interest in flood warning and preparedness programs. The chief objection to providing this linkage to the National Flood Insurance Program appears to be concern over the uncertain quality of local flood preparedness plans.

The result of this historical division and shifting of responsibility has been that flood preparedness planning has largely "slipped through the crack" in terms of federal interest and leadership. Without an interested agency champion, less effort has gone into research and application and the state of the art is not as advanced as it might otherwise be.

<u>Lack of Appreciation of the Need for Preparedness Planning as a Basis for Planning Flood Detection Systems</u>. Another common thread that perhaps explains some of the lack of attention to flood preparedness planning is a failure on the part of community planners, federal agencies and others to appreciate the relationship between the planning of flood detection systems and flood preparedness planning. While most would agree that it takes both a detection system and a preparedness plan to make up a comprehensive local program, little has appeared in the literature about the essential role that preparedness planning ought to play in the design of flood detection systems. This is due in part to the fact that a rational procedure for planning flood detection and preparedness programs has yet to be demonstrated.

A close look at the relationship between flood detection systems and flood preparedness plans suggests that planning should begin with an examination of the purposes to be served by the flood warning. Communities differ in the types of actions that they might want or find possible to carry out when a flood is impending and, depending on their resources and the nature of the tasks to be carried out, the warning lead time required for successful execution of the plan varies. Similarly, some areas might want to have a system that would reliably detect and warn of all impending flows greater than the 2-year flood while another community might be most concerned about only larger floods. Communities or parts of communities might also differ in the accuracy of flood prediction that is appropriate to their situation. A residential area located low along a riverbank may only be interested in whether or not it was going to flood while a hospital at a higher elevation might want considerably more accurate information on projected flood heights before beginning an evacuation that could involve significant hazards of its own.

These types of considerations suggest that flood detection systems should be individually designed to provide specific levels of performance that suit the needs of the community to be served. Over-design of the flood detection system will waste money and under-design creates vulnerability to error and failure. The performance criteria appropriate to a particular community can only be determined by analysis of the area at risk and consideration of the preparedness actions to be carried out.

Unfortunately, many flood detection systems now in operation were designed based not on what is required to provide some appropriate degree of reliability, accuracy and timeliness but rather on doing the best that could be done with the money the local sponsor was willing to invest. However, these types of systems lack the reliability to make up a flood detection and preparedness program that could stand as a flood loss reduction measure comparable to levees, floodproofing and other measures. If flood detection and preparedness programs are to be considered seriously as a potentially viable measure for an area, their performance must be predictable and this requires detailed design based on the pertinent hydrologic and other information.

Possible Approaches to Improvement

Given that present flood detection and preparedness programs are of less than desirable quality, What can be done to improve the situation? Any efforts toward that end should meet at least the following three criteria:

- The development of flood detection and preparedness programs should become more technically oriented with fuller coordination between the flood detection systems and the flood preparedness plans and with appropriate consideration of physical, economic and other factors.

- The historical lack of federal leadership and participation should be corrected without generating unnecessay controversy and concern over turf. Each agencies' role should be one that is appropriate to their major interests and which they are organizationally and technically capable of carrying out.

- Local flood detection and preparedness programs should be tied more directly to the areas of water resources and flood loss reduction to foster fuller consideration of the measure as a complement or alternative to structural and other nonstructural measures.

There are several alternatives that might be considered. One is to transfer back to the National Weather Service the responsibility for flood preparedness planning to restore things as they were before the organization of the Federal Emergency Management Agency Agency. This approach has numerous problems. First of all, it is not likely that the Federal Emergency Management Agency would be agreeable to giving up their responsibility and, if it was, the necessary legislation would might or might not be forthcoming. Second, it is not clear that the National Weather Service wants back any role in preparedness planning. That agency's needs for collection of more detailed data on rainfall and streamflow is served by the installation of local flood detection systems regardless of whether a preparedness plan accompanies the system. So long as flood detection systems without preparedness plans are attractive to the local sponsors that bear the cost, the National Weather Service has no incentive to expend much effort promoting flood preparedness plans. Even if the National Weather Service were willing to accept the responsibility for flood preparedness planning, there's no reason to believe that they could necessarily perform it particularly well. Their staff does not generally perform the types of studies required to develop a comprehensive and detailed preparedness plan and extensive training of field staff would be required. There is also a question about where a budget would come from for the activity. In addition, this approach would separate flood preparedness planning from other types of preparedness planning without creating the compensating tie to mainstream water resources and flood loss reduction planning.

A second alternative that might be considered is for the Federal Emergency Management Agency to begin fulfilling its responsibility to provide leadership to communities and states in the development of the flood preparedness plans. This would require extremely close cooperation with the National Weather Service to ensure that the two agencies' programs for flood detection and preparedness were coordinated and mutually supportive. There is no reason to believe that the Federal Emergency Management Agency will suddenly develop any strong interest in providing technical leadership in flood preparedness planning but, if it did, it would also face a problem of training staff to provide services to communities. This approach would require communities to deal with at least two federal agencies to design and implement a single program and without some other changes, it would probably not provide any significant amount of financial assistance in program planning or implementation. In addition, the history of Type I, Level B and other types of coordinated planning suggests that coordinated planning is not as successful as planning carried out under the leadership of a single agency. As in the previous approach, this one would do nothing to bring planning of flood detection systems and flood preparedness planning into the mainstream of water resources and flood loss reduction planning.

The third alternative which resolves many of these problems, is simply to quit thinking of every local flood detection system as part of an explicit measure for flood loss reduction and recognize things as they are. That is , there are flood detection systems, flood preparedness plans and, as a separate category, there could be comprehensive flood detection, warning and preparedness programs that combine these elements in an effective manner. If this view is taken, there is no problem with the National Weather Service continuing to encourage local flood detection systems of the type that are presently being installed and no fault if they do not pursue the concurrent development of warning arrnagements and a flood preparedness plan so long as it is recognized that the flood detection system is only intended to improve the agency's regular forecasts through availability of the locally collected data. Similarly, the burden on the Federal Emergency Management Agency would be lightened in that the agency would no longer be the culprit responsible for preventing full value being obtained from flood detection systems due to lack of flood preparedness plans. Since flood detection systems and flood preparedness plans developed under this general approach would not necessarily be intended to be significant measures for flood loss reduction, this approach also removes the Federal Emergency Management Agency from the position of being in charge of flood preparedness planning while being unwilling to recognize the measure in the rate setting for the National Flood Insurance Program. In addition, this alternative also reflects the view of communities that have invested in flood detection systems but have done little or nothing toward developing a flood preparedness plan.

Viewing flood detection systems and flood preparedness plans in this way alleviates any potential questions as to whether the Corps of Engineers or the Soil Conservation Service would be invading the National Weather Service's turf in taking an interest in flood warning and preparedness. If the Corps or the Soil Conservation Service were to take an interest in the field of flood warning and preparedness, their interest would be in the development of comprehensive and detailed programs that were intended to serve, either alone or in conjunction with other measures, as an explicit tool for flood loss reduction. While the agencies would surely consult with the National Weather Service and the Federal Emergency Management Agency, this approach would enable the more complex programs combining flood detection, warning and preparedness to be developed under the leadership of one agency. Planners of the Corps and Soil Conservation Service are also more accustomed to making the types of economic and other investigations required for development of comprehensive and detailed warning and preparedness programs and in a far better position to integrate such planning with existing or other planned measures for flood loss reduction.

This alternative would meet all of the criteria for improvement. Each of the concerned agencies would be left doing what it does best and presumably wants to do, thus improving federal leadership without any turf battles. Flood warning and preparedness programs would be tied more closely to water resources and flood loss reduction programs and the stage would be set for the Corps and/or the Soil Conservation Service to lead the way into a technically more advanced stage of planning in the field.

Providing a Practical Planning Technology.

As noted earlier, flood preparedness planning is considerably different than planning for hurricanes and other types of disasters. It would be foolhardy for the Corps or another agency to set out to prepare prototypes of comprehensive flood warning and preparedness programs without doing the research necessary to evolve a practical approach to the planning. A planning procedure should first be developed in draft form so that it could be tested as well as demonstrated in field studies and modified as necessary. The planning procedure should:

- Provide a rational way for integrating planning and design of comprehensive flood warning and preparedness programs that takes into account the differences in flood hazard and differences in response appropriate to individual communities. The planning procedure should base design on meteorologic and hydrologic data, evaluation of available resources, required warning time and accuracy of warning, and economic considerations. Consideration of the availability of funding should be secondary to the development of an effective program design. In the event that financial considerations require compromise of a plan or its incremental implementation over time, the planning procedure should provide a means to evaluate the resulting effect on the accuracy, timeliness and reliability of warnings and the effectiveness of response as well as on the potential economic benefits of the plan.

- Be developed based on a thorough evaluation of existing flood warning and preparedness programs with emphasis on investigation of programs that have been in place during a flood to obtain the benefit of their experience.

- Incorporate a comprehensive set of technical and other types of criteria defining the contents, level of detail, and other characteristics of what constitutes a minimally adequate flood warning and preparedness programs.

To complement the planning procedure, a "how to do it" manual or guide should also be developed. The literature is fairly rich in explanations of the general concepts of flood detection and preparedness and there are a variety of materials available concerning the technical aspects of flood detection and warning. However, there are few items that discuss the technical side of flood preparedness planning or the means of integrating detection, warning and preparedness considerations. A manual filling this need should be developed concurrent with the planning procedure for simultaneous distribution. In order to make the manual as useful as possible, it should supplement explanation of the planning procedure with introductory level materials on warning and preparedness and also provide the various types of reference materials necessary to apply the planning procedure.

THE FEBRUARY 1986 FLOOD IN THE CITY OF NAPA

by
John Weston Lindblad*,

INTRODUCTION

During the 3-day period February 16-18, 1986, the City of Napa experienced the most severe flood in this century. At the Third Street bridge near the downtown the flood water exceeded the top of the bridge railing, which is 3 1/2 feet above street level. Table 1-1 compares measured high water marks at the Third Street bridge for several flood events.

Table 1-1
High Water Marks at Third Street Bridge
Napa, California

Date of Flood	Elevation above MSL, feet
Feb. 27, 1940	15.80
Feb. 6, 1942	16.17
Dec. 23, 1955	13.71
Jan. 31, 1963	14.05
Jan. 21, 1967	11.94
Feb. 18, 1986	17.88

Heavy rainfall throughout the Napa River watershed for several days preceded the flood emergency. The river began to leave it's channel late in the evening on February 16 and reached the peak flooding limits late in the day on February 17. Flooding began to recede very early on February 18.

Approximately 2,500 homes were evacuated, mostly in the City of Napa. More than 150 businesses were damaged, along with over 1,000 residential units. P.G.&E's main transformer station on Burnell Street in Napa was flooded causing an extended power outage in a large portion of the central City.

The February, 1986, flood event had an estimated (by Gill and Pulver Engineers, 1986) recurrence interval of 50 years, and involved flooding from larger tributaries, as well as the river itself. Napa Creek, a tributary from the western foothills, joins the Napa River near the Center of the City, and contributed substantially to the flooding near it's confluence. Figure 1-1 attached is a map showing the February 17, 1986, flood limits.

*Public Works Director, City of Napa, California

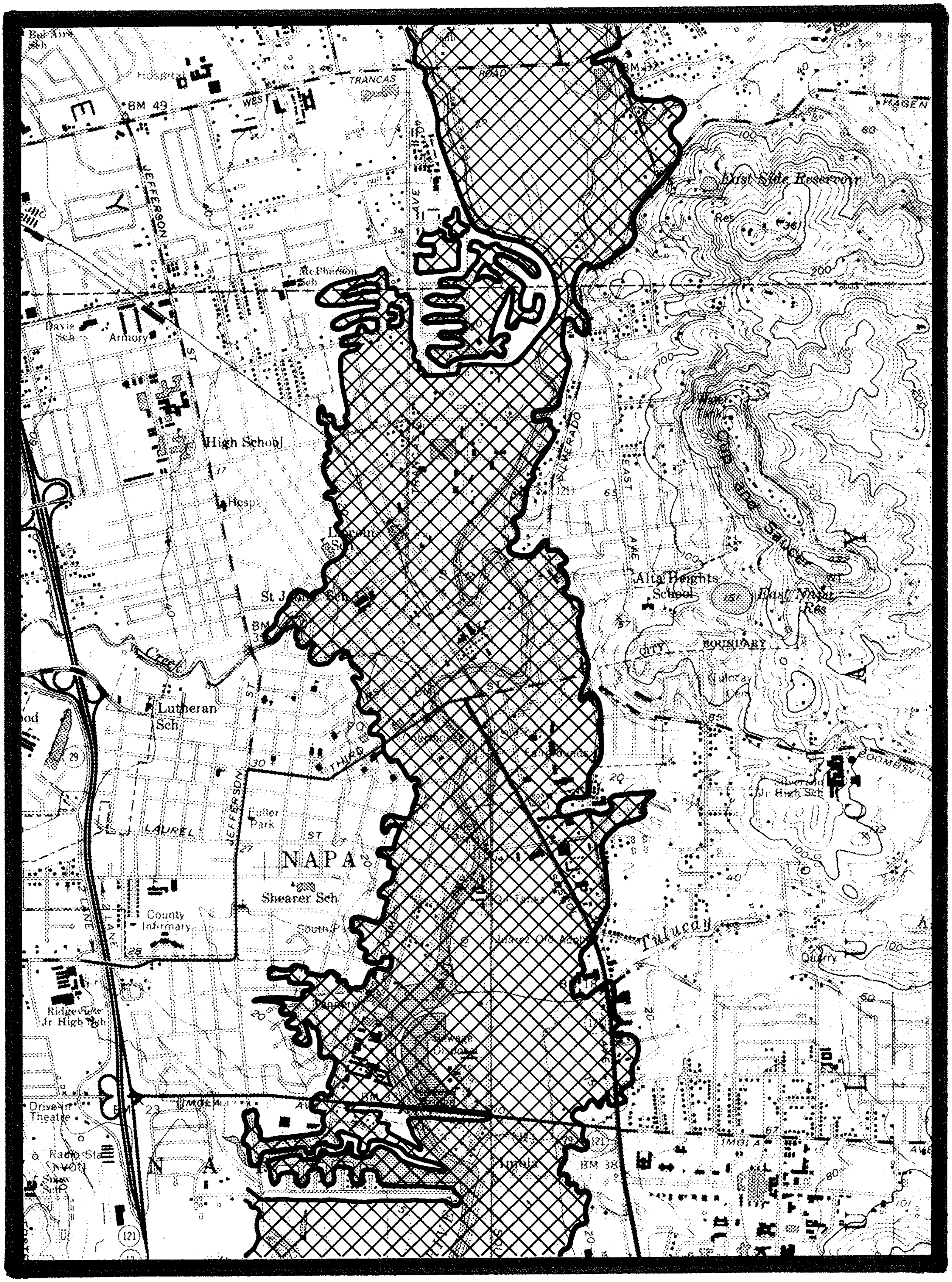

FIGURE I-I February 17, 1986 Flood Limits, City of Napa, CA.

COMMUNITY AND FLOOD HAZARD DESCRIPTION

The City of Napa, located on the Napa River in southern Napa County, has a current population of 54,300 within 16.9 square miles of corporate limits. The River passes through the heart of the City approximately 14 miles upstream from the mouth near Vallejo. Napa is a charter city governed by a five member City Council through an appointed City Manager. Napa is the County seat of Napa County and comprises 52 percent of the total County population.

The Napa River rises on the south slope of Mount St. Helena, at the intersection of Lake, Sonoma and Napa County boundaries, and flows for about 50 miles southeasterly to empty into Mare Island Strait, an arm of the Carquinez Strait. The river lies entirely within Napa County except for the southern 3.4 miles which flows through Solano County. The river drains a total area of 426 square miles.

There are eight major tributaries feeding the Napa River of which four are located within the City of Napa. The river varies erratically in width and depth throughout its length. The normal Napa River channel capacity through the City of Napa is approximately 12,000 cubic feet per second (CFS). The channel capacity varies and depends on the amount of vegetation and debris in the river, tidal conditions and the amount of sediment deposits in the dredged southern portion of the river.

Streamflow in the southern portion of the Napa River is affected by the changing tide conditions of the Bay. The tides affect the discharge and stage of the Napa River as far upstream as Trancas Street, near the northern City limits.

Floods of the same magnitude may result in different flood damage and areas inundated, depending on the efficiency of the main channel and the elevation and direction of the tide. This can be seen in Table 2-1, where high water marks at the Third Street Bridge are compared to recorded discharges at the Oak Knoll gage, which is about 5 miles north of Napa.

Table 2-1 Flood Elevation vs. Discharge

Date of Flood	Elevation above MSL at Third Street Bridge (ft.)	Discharge (cfs) at Oak Knoll
February 27, 1940	15.80	22,500
February 6, 1942	16.17	22,500
December 22, 1955	13.71	16,900
January 31, 1963	14.05	16,900
January 21, 1967	11.94	15,800
February 17, 1986	17.88	28,500

The frequency of flooding depends to a large extent on the definition of a flood. Flooding of some low-lying areas in Napa occurs when the streamflow exceeds 12,000 cubic feet per second. If this is used as the definition, the recurrence interval is about three years. However if major floods are used as the definition, the recurrence interval is about seven years.

The Napa River is pretty much a natural channel, altered only moderately by mankind. The lack of channel capacity to convey flood flows can be seen in Table 2-2, which compares existing channel capacity with peak flood flows.

Table 2-2 River Channel Capacity vs Peak Discharge

Location	Drainage Area (sq. mi.)	Estimated Channel Capacity, cfs	Peak Discharge,cfs 10 yr.	100 yr.
Oak Knoll Ave	218	7,500	18,500	32,700
Trancas Street	235	12,000	22,500	39,000
Imola Avenue	300	12,000	24,900	44,200

Major floods result in damage to commercial, industrial, residential and agricultural areas. Residential, commercial and industrial areas on both sides of the river are impacted. A substantial evacuation demand results from floods with a recurrence interval greater than 10 years.

FEDERAL FLOOD INSURANCE PROGRAM

The City of Napa is a participant in the regular phase of the National Flood Insurance Program. Figure 3-1 shows the Flood Hazard area and the adopted 100 year Floodplain and Floodway boundaries.

As a result of increasing pressure for residential development in the Floodway near the downtown area, about two years ago the Federal Emergency Management Agency (FEMA) and the City agreed that a restudy of the floodplan was needed. In November, 1984, FEMA initiated the restudy and employed Gill and Pulver, Inc., a Sacramento consulting firm to do the restudy. A report was issued by Gill and Pulver in July, 1986. The hydrologic study that accompanied the flood insurance study raised peak discharge values from those used for the existing adopted flood insurance program. Table 3-1 compares the 100 year peak discharges at Imola Avenue in Napa from the two studies.

Table 3-1
Increase in Napa River 100-year peak discharge
by 1986 Flood Insurance Restudy

Source	Napa River 100-year Peak Discharge at Imola Avenue, cfs
1979 Flood Insurance Study	40,000
1986 Flood Insurance Study	44,200

The City of Napa is using the 1986 Flood Insurance Study engineering data for review of development proposals pending issuance of the final documents by the Federal Insurance Administration.

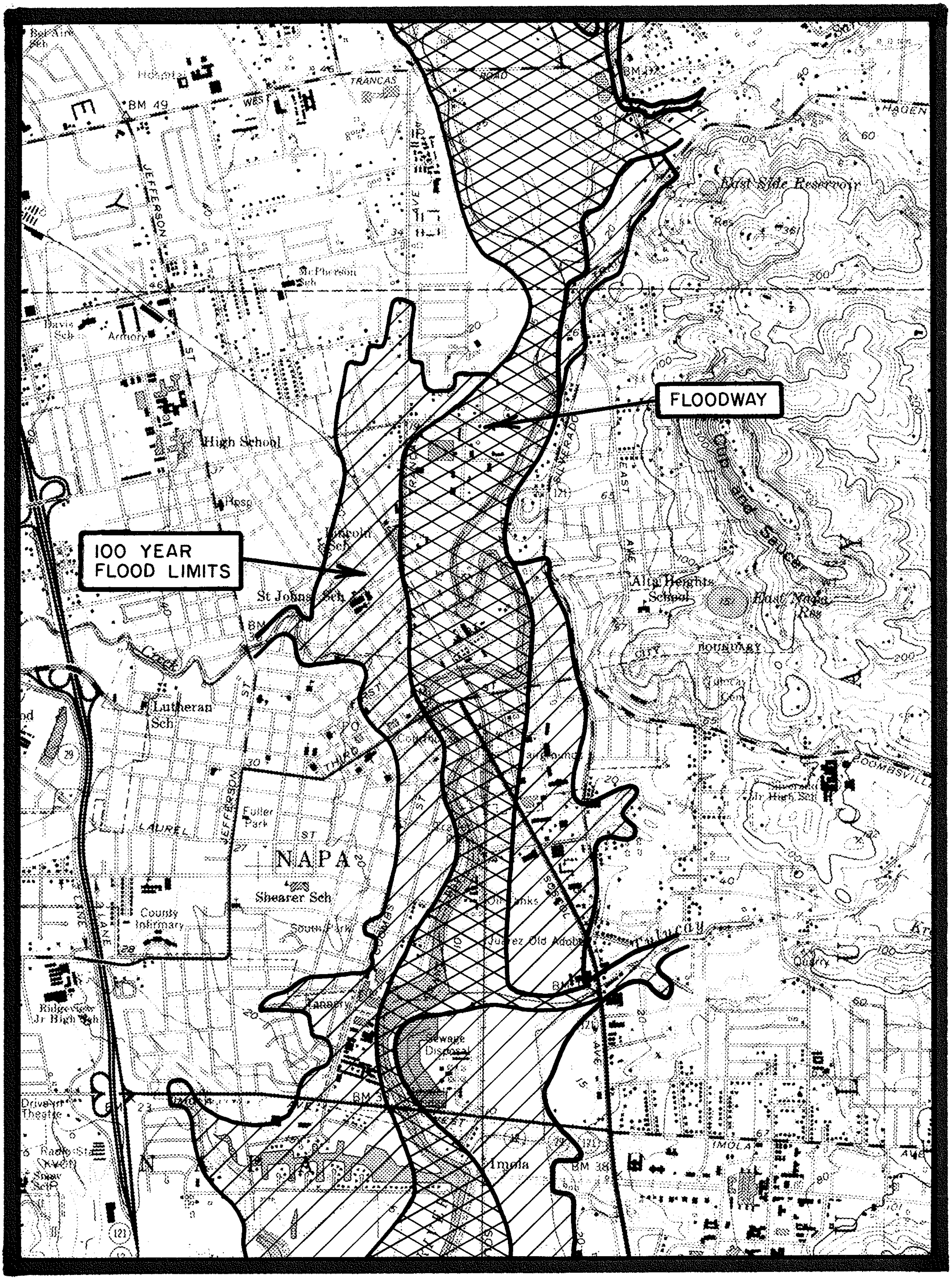

FIGURE 3-1 Flood Hazard Map, City of Napa, CA.

EXISTING FLOOD WARNING SYSTEM

The Napa County Flood Control and Water Conservation District provides a flood warning service for local agencies by utilizing information from the State Department of Water Resources Flood Forecast Center in Sacramento. Information received is disseminated by the District by direct contact with emergency management personnel in County and City government.

The State Flood Forecast Center receives direct information from three rain gages in Napa County, as well as many others throughout the State. They also receive direct readings from two gaging stations on the Napa River, one at Oak Knoll Avenue, approximately 5 miles north of the City of Napa, commonly referred to as, "Napa," and one at Zinfandel Lane, just south of St. Helena, commonly referred to as, "St. Helena".

The State Flood Forecast Center predicts peak river stage and time of occurrence for the two gaging stations from their data input, providing hourly updates. The County Flood Control District uses a telephone modem and printer to collect the Flood Forecast outputs.

In addition, the County Sheriff and City Police Chief receive direct telephone warnings from the State Flood Forecast Center and the Nation Weather Bureau.

The City of Napa maintains a color coded staff gage on the Napa River near Lincoln Avenue. It is calibrated to the nearest 0.5 feet, MSL datum, and by color painted on the staff provides warning of the river stage relative to the point when flooding outside of the river channel begins in Napa. It is located so it can be easily read by police patrol units and others.

EMERGENCY PREPAREDNESS

The County of Napa contracts with the State Department of Forestry for fire protection services in the unincorporated areas of the County. Thus the local head of the State Department of Forestry is also the County Fire Chief. He is also appointed Napa County Emergency Services Officer by the County Board of Supervisors, and is the County Official responsible for emergency preparedness. Being also a State Official he has direct access to State emergency resources. This arrangement proved very valuable during the February flood emergency, as State Office of Emergency Services assistance was easily and quickly obtained.

The City of Napa Fire Chief is Emergency Officer for the City, and coordinates directly with the County Emergency Services Officer. The City Fire Chief directs the City's emergency efforts including all City employees, outside agency assistance and volunteers. Through existing mutual aid agreements with other Cities and through the State OES, considerable additional personnel and equipment is made available to the Fire Chief. Within the City limits, the City is directly responsible for all emergency services.

The City maintains an initial supply of flood emergency material at the City Corporation Yard. Barricades, lights, sandbags, sand and various handtools are immediately available to City maintenance personnel to begin the flood fight. This material is supplemented from local stores and then from State OES sources.

THE FEBRUARY 16-18, 1986, FLOOD FIGHT IN THE CITY OF NAPA

The Napa River watershed is relatively small, and not very long. Therefore, floods in Napa occur with only a few hours warning, and the flood water recedes quickly. The lack of much warning causes the initial response to be disorganized and frantic, however, the limited time period results in the emergency ending before local resources, supplemented by State OES, are exhausted.

Emergency operations began mobilization shortly before midnight on February 16, 1986. An Emergency Command Center was established at Fire Station No. One, which is part of the Civic Center. The Civic Center is equipped with a standby diesel generator, which provides emergency power to the Police Station, Fire Station No. One and City Hall. All emergency operations were directed and coordinated from the command center. A nearby City office building was established as a volunteer center, directed by the command center. The Civic Center area is outside of the 100 year Napa River floodplain.

The City and County of Napa have a jointly operated extensive local radio network with repeater station located on mountain peaks surrounding Napa Valley. Police frequencies, fire frequencies, local government and highway maintenance frequencies are jointly used, and a combined dispatch center handles all emergency service requests. All City vehicles are equipped with two-way radios including many multichannel sets. In addition, a good supply of hand held portable radios operating on the same frequencies are available. Thus an independent communications network was immediately available to the Emergency Command Center, unaffected by electrical power outages.

Evacuation of residential areas began early on February 17, 1986, and proceeded throughout the day as flood water rose. Evacuation was carried out by City Fire Companies, supplemented by mutual aid assistance from other City Fire and State OES units, directed by the command center. School Buses and Napa City Buses were used to transport evacuees to centers established at the local high schools and a local church. Evacuees were housed and fed at these locations for several days. Through the State OES, portable kitchens were made available for feeding evacuees, volunteers and conservation camp personnel.

A number of small boats were secured by the Command Center to assist in evacuation. These were mostly volunteered by local citizens and were used to evacuate the few remaining citizens in heavily flood areas. A sandbag distribution center was established adjacent to Fire Station No. One. Sand was hauled by City and volunteer dump trucks from a local quarry, bags supplied from local and OES sources and filled by volunteers and the California Conservation Corps. Sandbags were picked up by residents and merchants to protect their property.

City owned and rented barricades were placed by street maintenance personnel to close flooded streets. Police aides, cadets and volunteers assisted the Police Department in controlling traffic and enforcing street closures.

The City Police Department established their own command center to coordinate emergency law enforcement. California Highway Patrol, County Sheriff and City Police units, assisted by police reserve personnel controlled traffic and operated extensive patrols. The law enforcement activities were very closely coordinated with the Emergency Command Center. The City Police Chief provided relief to the Fire Chief to maintain a continuously available emergency commander.

The Napa City Manager established a task force to coordinate all emergency activities including news releases, social services, volunteer relief agencies, etc. This task force met twice daily for several days during the cleanup period.

When the flood water receded, mud and debris was cleaned up by City maintained personnel, volunteers and crews from other cities. Fifteen nearby cities sent crews to assist with cleanup. Citizens stacked debris from damaged homes and businesses in the street areas, and this was hauled to the local landfill disposal site by City crews. The cleanup continued steadily for about 10 days and sporadically for an additional month.

SUMMARY
FLOOD WARNING SYSTEM
WEAKNESSES AND NEEDS

The existing State Flood Forecast Center is not able to accurately forecast floods in Napa. The time of occurrence is reasonably accurate, but the river flood stage forecast is not. Some of the reason for this are.

- Tide and wind data are not part of the input.
- Very localized, intense rainfall not measured by the existing data input.
- The short time of concentration and small watershed size.
- Reservoir and spillway information from Conn Dam-Lake Hennessey is not part of data input.

Over the past few years, this lack of accuracy has reduced considerably the affectiveness of the warnings. Local officials have received too many warnings for floods that have not occurred. For the February, 1986, event the river stage forecast was more than one foot below the actual peak stage. Because of this local officials have a tendency to rely on their own experience and knowledge more than the forecasts.

The short time of warning in advance of a flood has always been a problem in Napa. In part because of it's organizational structure, the City of Napa has been able to mobilize the emergency effort fairly quickly, however, some additional specific training for key City personnel in the area of flood disaster response would be helpful.

Reliable flood forecasts would be of considerable assistance if the information was disseminated efficiently to the right people. Local agencies emergency disaster manuals could develop systems for using the forecast information to quickly activate emergency plans, issue public information bulletins and schedule evacuation and emergency protection of areas.

With the likelihood of structural flood protection measures remote, Napa could benefit from stricter land use regulations and better public understanding of flood hazards. More direct assistance from State and Federal agencies would help to overcome political and other barriers to better flood mitigation planning.

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Gill and Pulver Engineers, Inc. "City of Napa Flood Insurance Study Hydrologic Engineering Report, Napa River, Napa, California", December 1985.

U.S. Department of Housing and Urban Development, Federal Insurance Administration "Flood Insurance Study, City of Napa, California, Napa County", March 1979.

Real-Time Monitoring and Flood Forecasting

by W. A. Evans, Jr., P. E., M. ASCE*

Abstract

An automated flood warning system is now serving the 2,700,000 residents of Houston, Harris County, Texas. Real-time rainfall and river level data from more than 150 sensors are automatically transmitted to a microcomputer at the Harris County Flood Control District Offices (HCFCD). Stream status and crest predictions are made available to flood prone citizens in the flat coastal plains of Harris County, covering more than 20 watersheds and 1,740 square miles.

Introduction

In responding to a long history of flood problems in the county, the Harris County Commissioners Court authorized the development of a flood warning system in order to:

1) Assist Harris County residents in decisions and activities related to property protection and evacuation during potential flood situations.

2) Assist the HCFCD, local governments, and other agencies in scheduling and manning flood related activities, and

3) To gather data for hydrological and hydraulic analyses by HCFCD engineers and others in watershed planning and management.

System installation began in 1982 and has expanded each year since. Equipment and computer software were supplied by Sierra-Misco, Inc. and its subsidiary International Hydrological Services.

The system was named one of the Ten Outstanding Engineering Achievements of 1984 by the National Society of Professional Engineers.

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Real-time rainfall and stream level data from more than 150 sensors at 62 sites are automatically collected and transmitted by VHF radio to the HCFCD Offices. Sensors report when the monitored variable changes status. This enables remote rainfall and river sensors to transmit information to the HCFCD Offices at rates that are directly proportional to the intensity of the storm event. Rapidly changing field conditions can be instantly appraised and responses initiated accordingly.

Figures 1 and 2 show manometer and pressure transducer stage configurations. Interface to existing manometer and stilling-well gages are also easily accomplished with sproket drive encoders. Note the nitrogen bottle enclosure and solar battery charge panel in Figure 1.

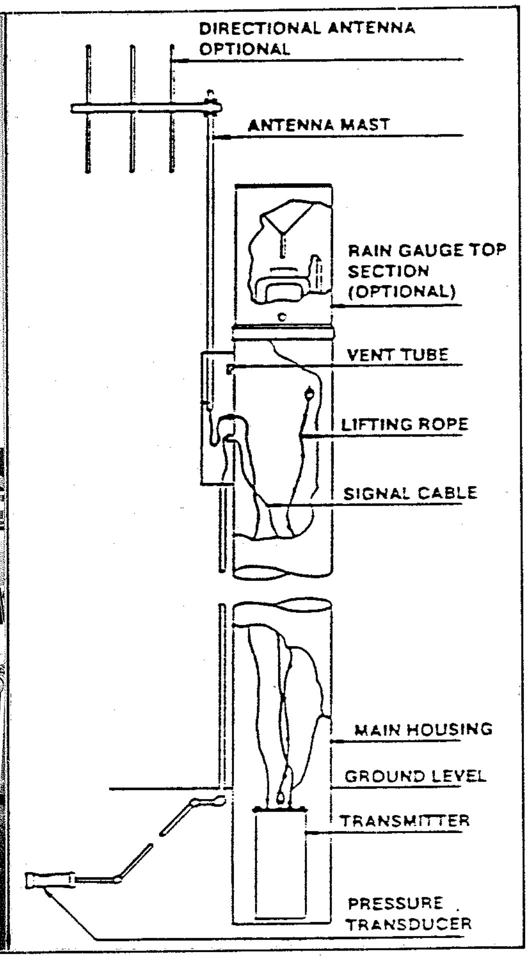

Figure 1 Tipping Bucket Raingage and Manometer Stage Gage.

Figure 2 Cross Section of Pressure Transducer Stage Gage Site

In the case of a tipping bucket raingage, each tip of the bucket signals a change in status by the occurrence of an additional millimeter (0.04 inches) of rainfall. When the bucket tips, a battery operated radio transmitter is turned on and in less than 0.25 seconds its message is transmitted and the transmitter is shut off again. As the rainfall intensity increases, the bucket tips more frequently which in turn increases the data reporting rate. Thus, by using intelligence available at the remote sites, the real-time event reporting enables monitoring of changes in storm characteristics as soon as they occur.

An IBM PC AT microcomputer is used at the HCFCD to coordinate the data acquisition, management, analysis, and communication tasks. Equipped with a multi-user, multi-tasking operating system, the microcomputer automatically handles

1) keyboard requests for data, plots, maps,
2) data acquisition from the field sensors,
3) three dial-in telephone lines for outside users,
4) data distribution to the office computer system,
5) a wall map display,
6) a remote beeper alarm system,
7) database management, and
8) automated streamflow forecasting.

Keyboard requests for information are often for displays of current or historical information from the database. Table 1 shows a precipitation summary as it was obtained at 757 a.m., March 14, 1985. Note that 2.44 inches of rain occurred in the most recent 30 minute period at station #1540. With real-time information such as this, the HCFCD was able to remain accurately appraised of the severity of the storm event.

For rainfall sensors, approximately two years of data are available on-line at any time. Historical summaries from this data base are easily obtained in keyboard selectable time intervals for any dates in memory.

Outside users such as the National Weather Service, the U.S. Army Corps of Engineers, and the U.S. Geological Survey can access the real-time information through dial-in telephone lines. In addition, HCFCD staff members can monitor storm conditions using remote terminals. This is especially valuable if storm conditions suddenly arise during off-duty hours. Staff members can dial in to the computer to review the developing conditions and initiate emergency procedures if necessary.

Harris County Flood Control District					
3/14/1985 757					
	# 720	#1520	#1540	#1720	#1740
Date/Time	3/14	3/14	3/14	3/14	3/14
Value of	0755	0755	0756	0756	0750
Last Rpt.	628	704	802	657	766
Precipitation					
Last 10 min	0.04	0.12	0.59	0.43	0.04
Last 30 min	0.20	0.94	2.44	1.10	0.12
Last 60 min	0.31	1.57	3.03	1.26	0.24
For 24 hours					
Ending at 700	0.04	0.16	0.12	0.04	0.00
Since 700	0.31	1.54	3.03	1.26	0.24
600 Thru 700	0.04	0.16	0.12	0.04	0.00
500 Thru 600	0.00	0.00	0.00	0.00	0.00
400 Thru 500	0.00	0.00	0.00	0.00	0.00
300 Thru 400	0.00	0.00	0.00	0.00	0.00
200 Thru 300	0.00	0.00	0.00	0.00	0.00
Since 700	0.31	1.54	3.03	1.26	0.24
100 Thru 700	0.04	0.16	0.12	0.04	0.00
1900 Thru 100	0.00	0.00	0.00	0.00	0.00
1300 Thru 1900	0.00	0.00	0.00	0.00	0.00
700 Thru 1300	0.00	0.00	0.00	0.00	0.00

Table 1. Precipitation display for a five rainfall station group.

Every thirty minutes, the microcomputer automatically sends the latest data to a Wang office information system. The Wang System then allows distribution of the data to any word processing/data terminal at the HCFCD facility. Special displays that show the current stage at critical locations, historical flood information at that site, recent trend information about stage and rainfall, and elevations of buildings in the immediate area. These displays are extremely useful in answering the many site specific questions from the public during a flood event.

To further enhance the interpretation of field conditions during a storm event, the microcomputer controls a wall map display. See Figure 3. For each rainfall and river sensor in the system, a light is located at the appropriate position on the map. When rainfall is first reported (1 mm) at a field site, the light is turned on. If the rainfall amounts exceed predefined alarm criteria, the light starts to flash. When the rainfall rate falls below the alarm rate, the light stops flashing and finally is turned off 30 minutes after the rain stops. The movement of a storm system across Harris County can be quickly assessed by a glance at the map display.

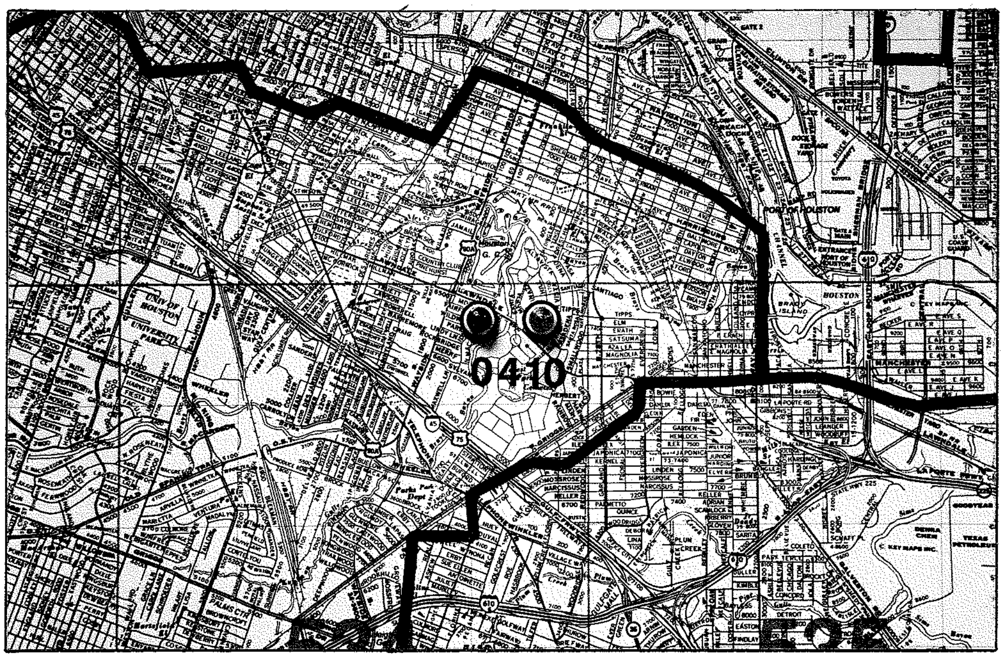

Figure 3. Map Status/Alarm Lights

Alarm conditions can be set for any sensor in the network. Variables can be tested for maximums, minimums, and rates of change. When an alarm criterion is exceeded, the microcomputer sounds an alarm on the on-board speaker, flashes a message on the console screen, flashes the appropriate light on the wall map display, and uses the telephone to dial a commercial beeper service. When the commercial beeper service is called by the microcomputer, the beepers carried by HCFCD personnel are activated. Once notified, HCFCD personnel can then dial in to determine the cause of the alarm or come directly to the operations center to begin the emergency response.

An automated streamflow forecast system is also operated by the microcomputer. The Sacramento Soil Moisture Model is continuously on-line. Every 15 minutes the model reviews the most recent rainfall data and provides an updated forecast based on the observed rainfall. In addition, up to five different scenarios of future rainfall are also considered in generating the forecast hydrographs. See Figure 4. This allows the user to examine several different alternatives for possible future action. Currently, ten points have been calibrated within three watersheds and are being forecast in real-time. Up to twenty-five (25) gaging points can be forecast in this manner. Figure 5 shows an example forecast hydrograph with five different scenarios of future rainfall. Figure 6 shows a real-time forecast and the actual observed river level. Rainfall is plotted at the top of the CRT screen.

Oct 16 86 14:18:32

Simulation point # 3 (Sim's Bayou-HiramClarke) Forecast extensions

	Case # 1	Case # 2	Case # 3	Case # 4	Case # 5
Alarm	OFF	OFF	OFF	OFF	OFF
	1.00in. in 30 min	0.50in. in 30 min	1.50in. in 30 min	0.08in. in 30 min	2.00in. in 1 hr
	________	________	________	then 0.00in. in 2 hrs	________
	________	________	________	then 0.50in. in 30 min	________
	________	________	________	then 1.50in. in 3 hrs	________
	________	________	________	then 0.50in. in 30 min	________

Change a forecast extension (y/n) ?

Figure 4. Rainfall Forecast Cases

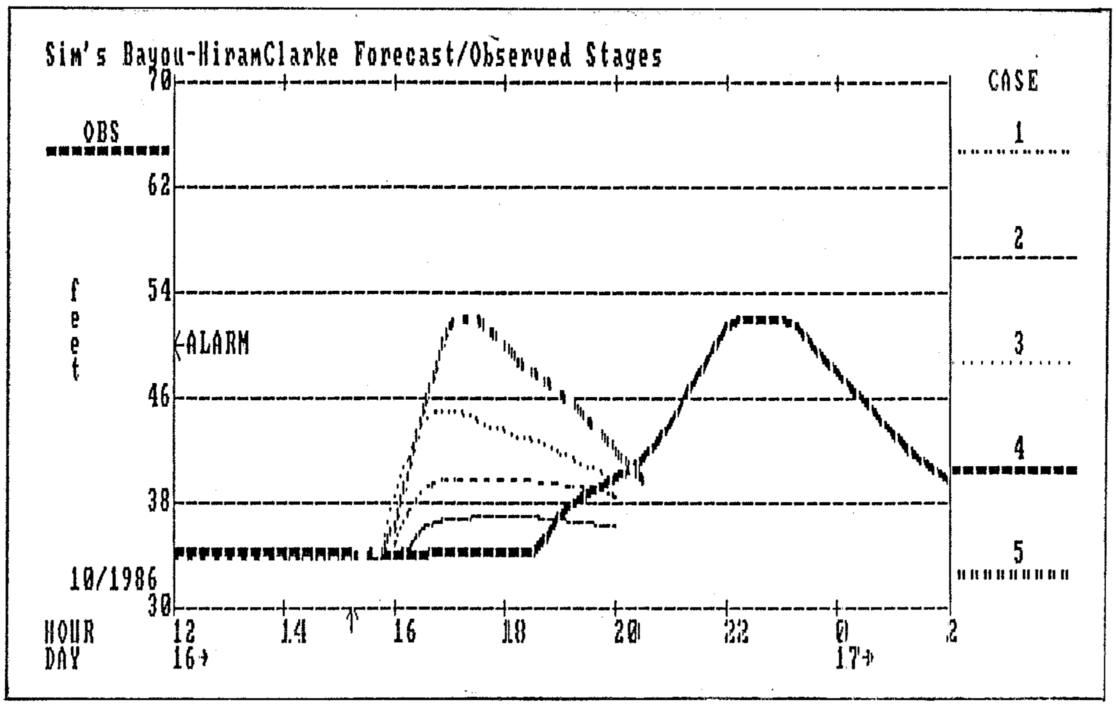

Figure 5. Forecast Plots.

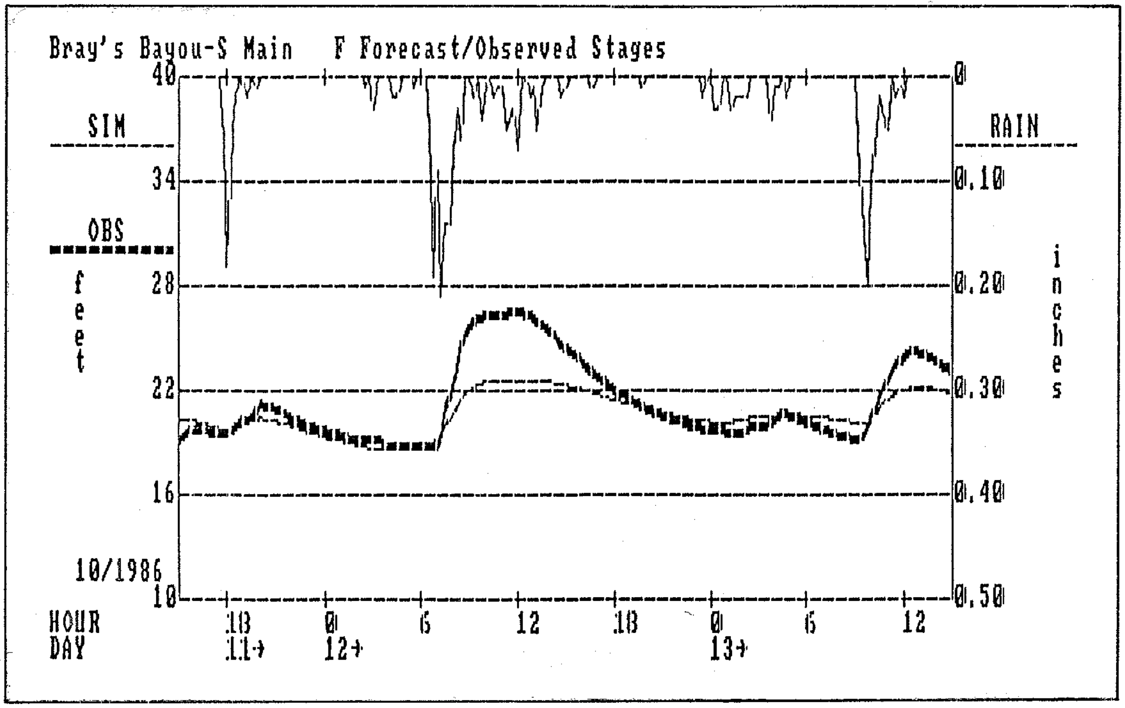

Figure 6. Forecast versus observed.

The Enhanced ALERT Automated Flood Warning System is the center of the HCFCD Flood Watch Program. During the threat of a flood event, the Flood Control District mobilizes to meet the special needs of affected citizens and other government agencies for up-to-date information. The level of mobilization depends on the type and extent of an event in accordance with the District's Flood Watch Manual. See Table 2. Figure 7 shows the responsibilities of the Flood Watch organization.

Hurricane threats or widespread potential for overbank flooding results in a full Staff Alert Phase. Normal operation of the HCFCD is suspended and the efforts of the 900 employees are devoted to flood related activities.

FLOOD ALERT PHASES & MANNING

NORMAL CHECK RAIN/LEVELS BY REMOTE COMPUTERS. ALERT ALARMS VIA RADIO BEEPERS AND PRIVATE WEATHER CO CONTACTS

MONITOR EXPERIENCING HEAVY RAIN WITH STREET FLOODING AND POTENTIAL OF ONE OR TWO CHANNELS TO TOP

CAMP GENERAL STREET FLOODING AND/OR SOME CHANNELS OUT OF BANK

STAFF COUNTY WIDE FLOODING AND/OR THE THREAT OF HURRICANE. NORMAL OFFICE OPERATIONS SUSPENDED

MANNING PER SHIFT	MONITOR	CAMP	STAFF
SHIFT LEADER	1	1	1
RADIO OPERATOR	1	1	1
GAUGING CREWS	0-2	1-2	3-6
SYSTEM OPERATOR	STANDBY	1	1
TELEPHONE OPERATORS	1-2	2-4	3-10
ENGINEERING COORD.	STANDBY	1	1
ENGINEERS	0	1-2	2-4
AGENCY COORDINATOR	0	STANDBY	1
MAINTENANCE COORD.	STANDBY	1	1
CAMP CREWS	STANDBY	0-6	6
SWITCHBOARD OP	0	0-1	1

TABLE 2. FLOOD ALERT PHASES AND MANNING

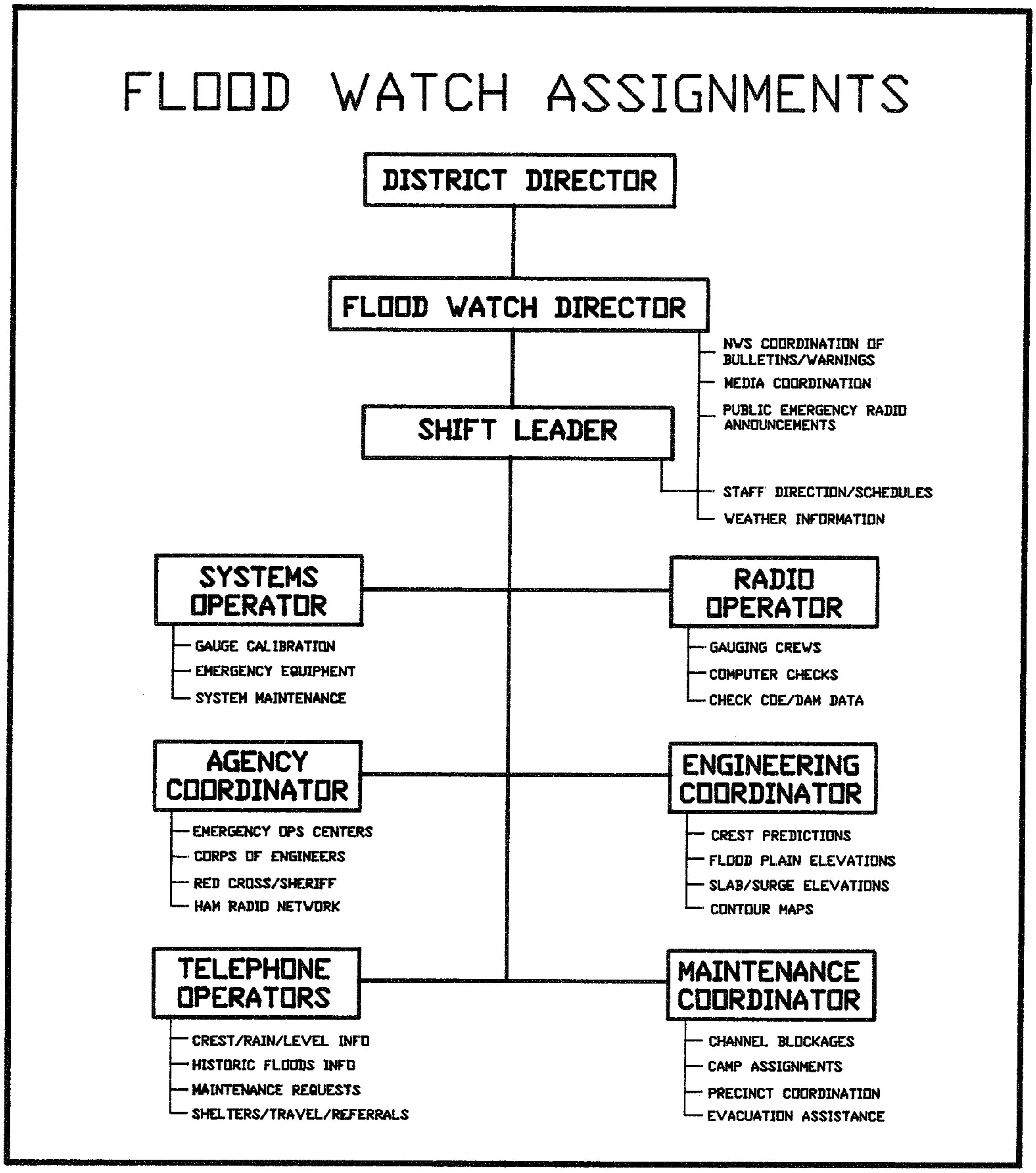

FIGURE 7. FLOOD ALERT RESPONSIBILITIES

The Operations Room, Figure 8, contains computer terminals, radios, and the wall map display. This room, computers, and telephones are powered by an emergency engine-generator unit.

Figure 8. Flood Alert Operations.

Manual gaging crews are dispatched to sites not yet included in the automated real-time system and, where possible, to check calibration of the automated gages. The District provides around-the-clock telephone assistance during floods. In addition to stream and rainfall data and forecasts, residents are referred to the proper agency for other vital safety information.

The NWS, USGS, and the U.S. Army COE access the hydrometeorological data via dial-in telephone. Close coordination with the National Weather Service is maintained to assist in localizing Flood Watches, Warnings, and obtaining quantitative precipitation forecasts.

Conclusion

Previously the HCFCD relied on gaging crews hampered by street flooding to gather data on rising creeks and bayous. The spotty coverage and the lack of rapid computer-aided forecasting limited the effectiveness of the District.

Now with the state-of-the-art equipment and software, the Harris County Flood Control District can accurately track storm conditions and forecast potential problem areas. Timely information is passed on to affected residents and agencies in Harris County to enable them to effectively meet the flood challenge.

VILLAGE CREEK FLOOD WARNING SYSTEM

By Gene R. Russell[1]

General

Village Creek is located in Jefferson County, Alabama, and to a large extent is within the City of Birmingham. This is the largest metropolitan area in Alabama with a population of approximately 400,000. Flooding within the basin has been a problem for many years, but changes within the drainage area and modifications to the channel have tended to intensify the problem. The two largest floods of record for Village Creek occurred in March 1970 and December 1983. The 1970 flood is considered to be about the 100-year flood event, while the 1983 flood is about a 30-year flood event.

Basin

The entire Village Creek basin contains about 101 square miles and is 26 miles long. The basin is approximately 1 mile wide for the upper 8-mile reach and 5 miles wide for the remaining portion. The Creek winds in a southwesterly direction through the heavily urbanized section of north Birmingham to Ensley, then through Bayview Lake to its juncture with the Warrior River a few miles further downstream.

Flash flooding is of greatest concern in the reach above Bayview Lake where the basin is considered to be about 90 percent developed. Development along this reach of the flood plain is urban/industrial up to the stream bank. Land use in the flood plain is 24 percent residential, 3 percent commercial, 9 percent institutional, 35 percent industrial, and 29 percent other uses such as water areas, vacant lots, disposal areas, etc. The water is of low quality, unable to sustain aquatic life in the urbanized areas through which it passes. A basin vicinity map is shown on Figure 1.

There are many hundreds of family housing units within the Village Creek flood plain, with those nearest the creek generally in the low-to-moderate price range. Most of the industrial developments are located further from the creek, but still within the flood plain. A flood of the 100-year frequency would cause severe damage and would actually inundate about two-thirds of the municipal airport.

During the studies to provide flood protection for the Village Creek area, the stream above Bayview Lake was divided into seven reaches and the impacts of alternative plans were analyzed for each reach. The various plans involved channel improvements, bridge modifications or removals, landscaping, and removal of affected structures. The presently recommended plan provides for a combination of these measures. The water surface elevations throughout

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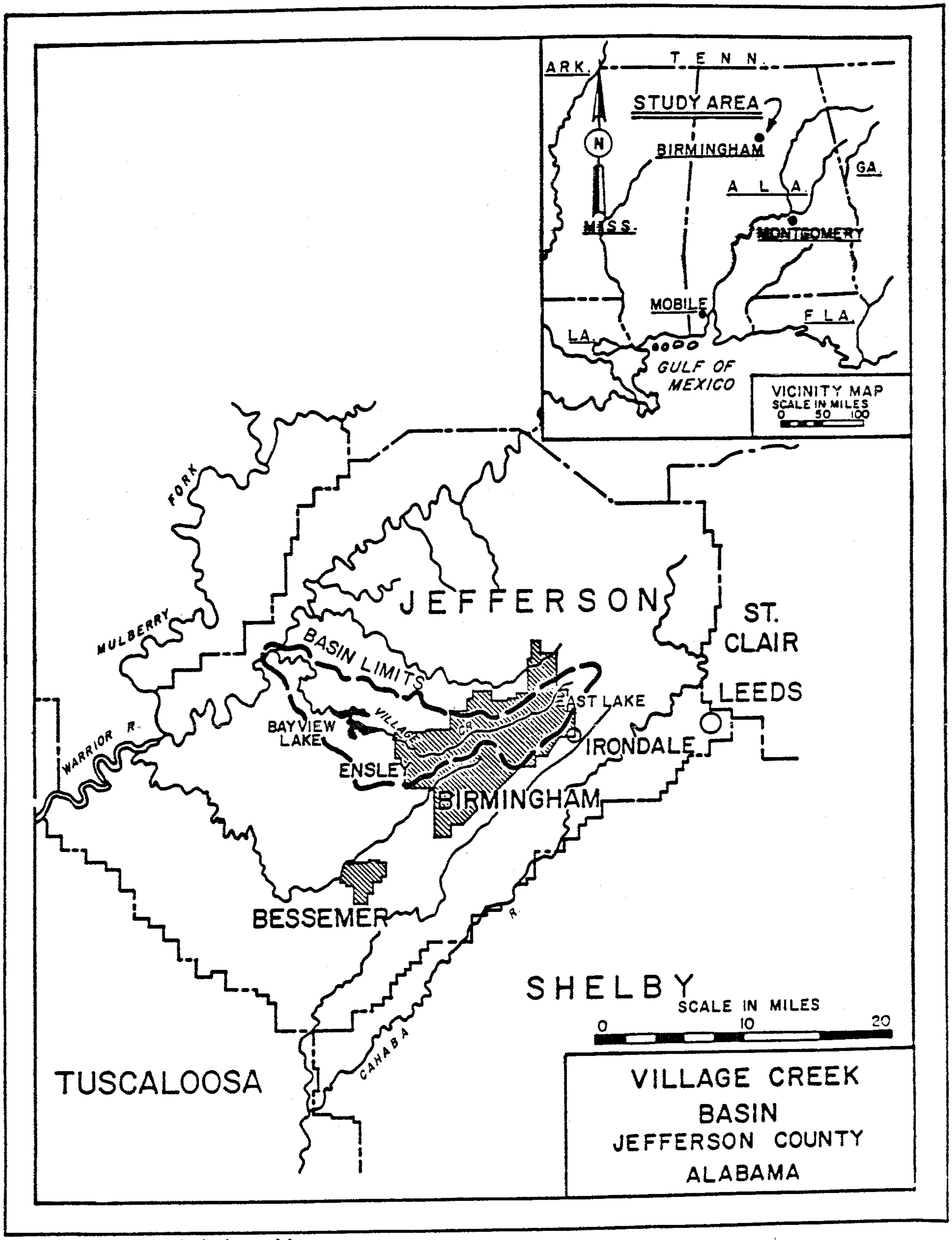

Figure 1 Vicinity Map

the length of the project will be reduced an average of about 1.2 feet for the 10-percent flood and about 0.4 feet for the 1-percent flood due to channel and bridge modifications. In addition, over 600 structures below the 15-year-frequency flood will be removed. Table 1 shows the average annual flood damage prevented by this project.

TABLE 1
AVERAGE ANNUAL FLOOD DAMAGES

Return Internal	Without Project	Remaining With Project	Prevented By Project
2	$1,670,000	-0-	$1,670,000
5	3,335,000	-0-	3,335,000
10	4,065,000	-0-	4,065,000
25	4,425,000	$3,075,000	1,350,000
50	4,685,000	3,905,000	780,000
100	4,940,000	4,215,000	725,000
SPF	5,355,000	5,145,000	210,000
Average Annual	$1,353,000	$ 242,000	$1,111,000

As can be seen from Table 1, there remain areas subject to significant flood damages above the 15-year-frequency flood. Also, much of the area cleared below that level may be utilized as parks or other activities that may attract people into the flood plain. For these reasons, a flood warning system has been incorporated as an integral part of this project. The Mobile District has a long history of installing and maintaining reporting gages for flood control and other uses associated with the District's many reservoir projects. However, the District has not installed a sophisticated flood warning system for a small, flashy, uncontrolled stream such as this. Designs for several such systems including Village Creek have been undertaken but, to this date, none have been installed.

Design criteria

One of the first priorities in designing a flood warning system was to define the objectives. An outline of the needs and objectives was developed to guide the design and selection process. Basically, this outline was as follows:

EARLY DESIGN CRITERIA

1) Need for automatic measurement of stream heights and real-time transmission of this data to a central control point.

2) Need to have predictive ability to give warning time to residents.

3) Need for a comprehensive warning distribution plan.

4) Need for a comprehensive evacuation plan (provisions for temporary housing, etc.).

Warning time

In further designing the Village Creek flood warning system, it was necessary to determine how much warning time could be expected (for both the worst and best cases). Hydrographs produced by HEC-1 models were examined to determine the rate of rise for different rainfall patterns. Figures 2 and 3 present hydrographs for an observed storm at 24th street and for the synthetic 100-year flood at two locations. These hydrographs give a generalized view of the rate of rise that may occur during any future flood. Also shown on the 100-year flood hydrograph are the points representing flow frequencies for smaller floods.

After examining several hydrographs, it became obvious that warning time is a function of several parameters including antecedent conditions, distribution of rainfall, and the rate and volume of rainfall. An intense rain storm over the entire basin could result in two hours or less of effective warning time. A longer warning time might be available for moving frontal systems or locally intense thundershowers; however, if more than 6 to 8 hours are to be gained, it will be necessary to make forecasts based on expected rainfall. In general, forecasts based upon expected rainfall are not considered a good practice due to many obvious reasons, but such forecasts can be a valuable tool in the hands of the emergency operations personnel. Forecasts based on expected rainfall will not usually be released to the public, but emergency resources can be mobilized and ready when it appears that a major flood is likely.

Selection of warning systems

With the magnitude of the potential flooding defined and the warning time known, the actual selection and design of automated flood warning systems could be undertaken. Since any system would eventually be operated and maintained by local authorities, it was necessary for the Corps to coordinate development and design with representatives from the City of Birmingham. For this reason, discussions with City officials were held to narrow the possible design plans. It was decided that the Corps would present several options to the City for consideration. Three types of flood warning systems were considered by the Mobile District including minimal float switch systems, custom design systems, and Automated Local Evaluation in Real Time (ALERT) systems. In addition, three different plans based on the ALERT concept were developed to demonstrate the range in both capability and cost available to the user. The costs for these systems were estimated at $8,500 for the minimal float-switch, $26,800 for the custom design, and from $31,300 to $46,100 for the ALERT systems. Figure 4 gives a generalized comparison of advantages and disadvantages of each system. The system selected by the City of Birmingham was the more comprehensive ALERT system at $46,100, but with more recent cost estimates and the addition of an additional base station, the present cost is expected to be about $106,000. Figure 5 contains an itemized cost estimate for the selected ALERT system. A general description of each system is contained in the following paragraphs.

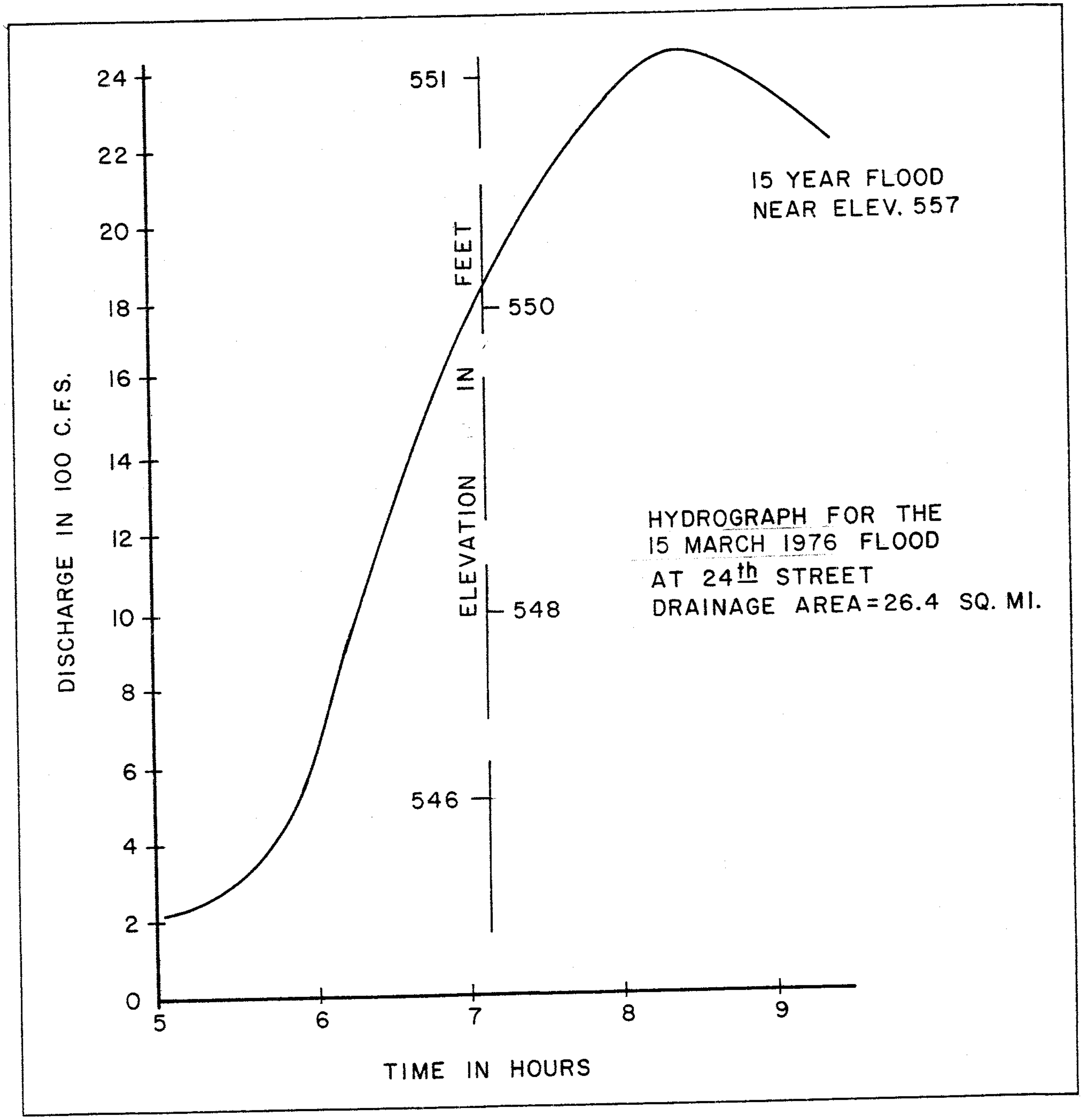

Figure 2 Flood Hydrograph – 15 March 1976

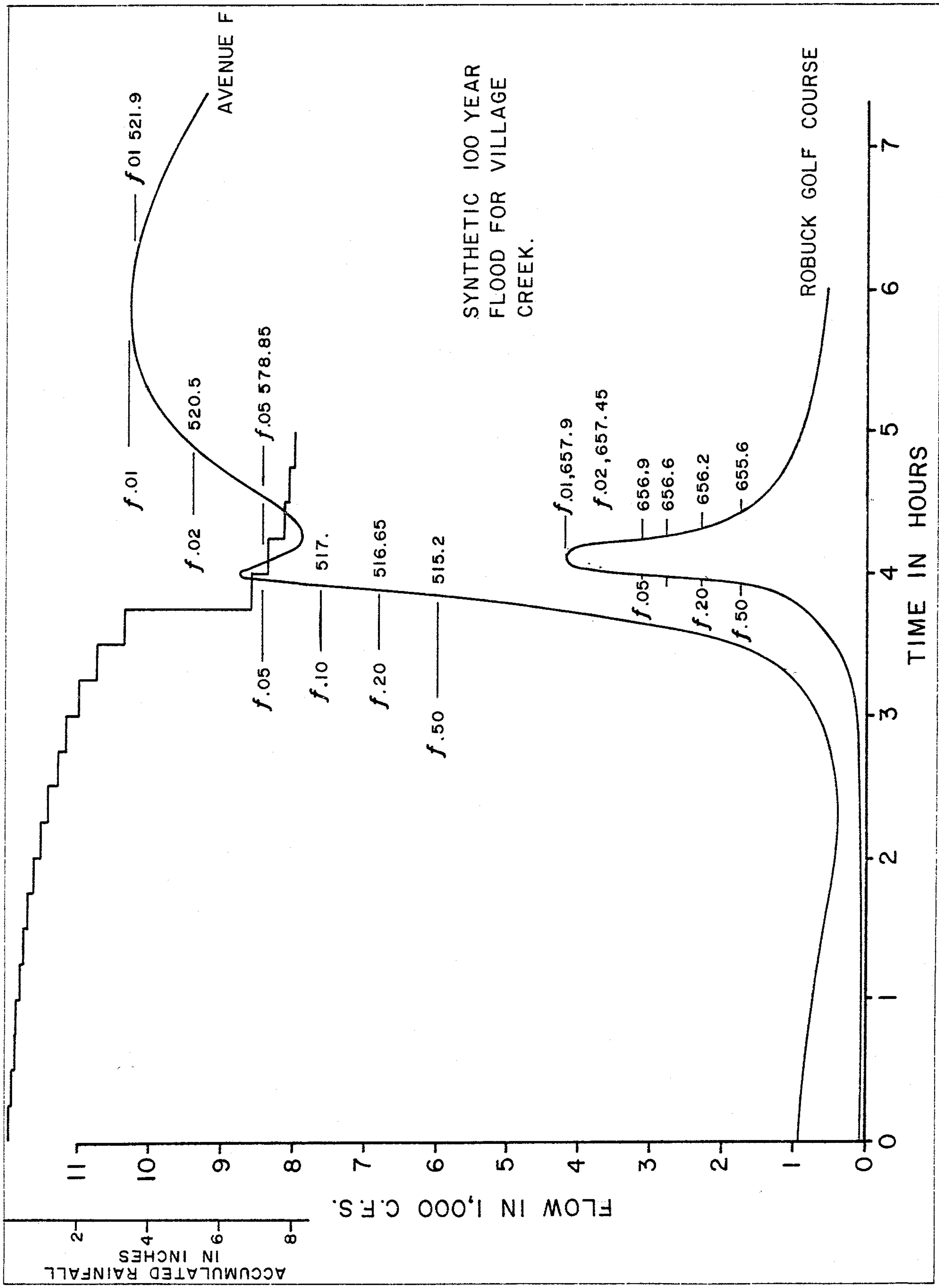

Figure 3 Flood Hydrograph—100 Year Storm

COST ESTIMATE

	Unit Price	Qty	Total Cost
Field Equipment			
Automated combination river stage rain gage	$ 4,340	3	$ 13,020
Automated single-purpose rain gage	2,790	1	2,790
Repeater station	5,600	1	5,600
Base Station			
Antenna	395	3	1,185
Receiver/Decoder	2,600	3	7,800
Central site display, minicomputer and software for enhanced ALERT	10,000	3	30,000
Dot matrix printer with cable	950	3	2,850
Uninterruptable power supply, 250-watt	1,600	3	4,800
Autoanswer phone modem	350	3	1,050
Cables and connectors	130	3	390
Test Equipment			
Test switch	40	1	40
Battery charger 8 Amp battery	40	1	40
Battery charger 23 Amp battery	135	1	135
Battery discharger	180	1	180
Wattmeter	350	1	350
Remote station tester	3,300	1	3,300
Spare Parts			
Transmitter	2,400	1	2,400
Battery 8 Amp hr	60	5	300
Battery 23 Amp hr	130	1	150
Omni antenna with 15-foot cable	100	1	100
Tipping bucket rain gage	200	1	200
Equipment Total Cost			$ 76,660
Less 10-1/2% GSA Discount			8,040
Total			$ 68,600
Estimated installation cost			$ 15,000
Total installed cost			$ 83,600
Calibration for ALERT software			6,000
Plus 20% contingency			$ 16,400
TOTAL			$106,000

Figure 5 Itemized Cost Estimate for Alert System

Float-switch system. This warning system for Village Creek consists of a float-switch device housed in a stilling well located upstream of the flood-prone areas. When the water level reaches a pre-selected stage a circuit is closed and an alarm is sounded over a dedicated telephone line to a local authority. The local authority then verifies the flood hazard by visual observation and proceeds with the warning/evacuation plan.

Custom system. The custom system is similar to the float-switch system except that several stages can be measured (up to five in the Village Creek system). Notification is by radio transmitter to a designated base station and there is a battery "back-up" for periods of power outages. With five float switches, this system can supply stage vs. time information, yielding valuable information about the actual lead time available.

ALERT system. This option is based on a system developed by the California-Nevada River Forecast Center of the Western Region of the National Weather Service. It is a fully automated system consisting of both rainfall and river gages that periodically report to computerized base stations providing the data needed to compute river stage forecast. Three separate systems were designed using the ALERT concept with varying numbers of field gages and base stations.

The ALERT system selected by the City officials consists of the following components:

1) Three combination river stage/rainfall stations and one single purpose rainfall station, located strategically throughout the basin.

2) One repeater station located on Red Mountain to relay radio messages from the stations to the Emergency Operations Centers (EMC).

3) Eventually, there will be three EMC's in Birmingham, Ensley, and the National Weather Service Office in Homewood.

4) Mini-computers and associated software located at the EMC for Automated Data Collection and processing.

Figure 6 shows the approximate locations for each of the automatic reporting stations and Figure 7 depicts typical gages and equipment for the system. It is expected that data will be transmitted through the repeater stations to the base stations at pre-determined time intervals or whenever a given event has occurred. Time intervals for reporting data can range from a few minutes to several hours, and rainfall of one millimeter will trigger an event report.

The mini-computers located in the base stations will receive, archive, and process all of the incoming data. The ALERT software is capable of maintaining a continuous hydrologic model of the basin and will provide stage forecasts at frequent intervals. At any time that critical stages are forecast or actually occur, or when certain given volumes of rainfall occur,

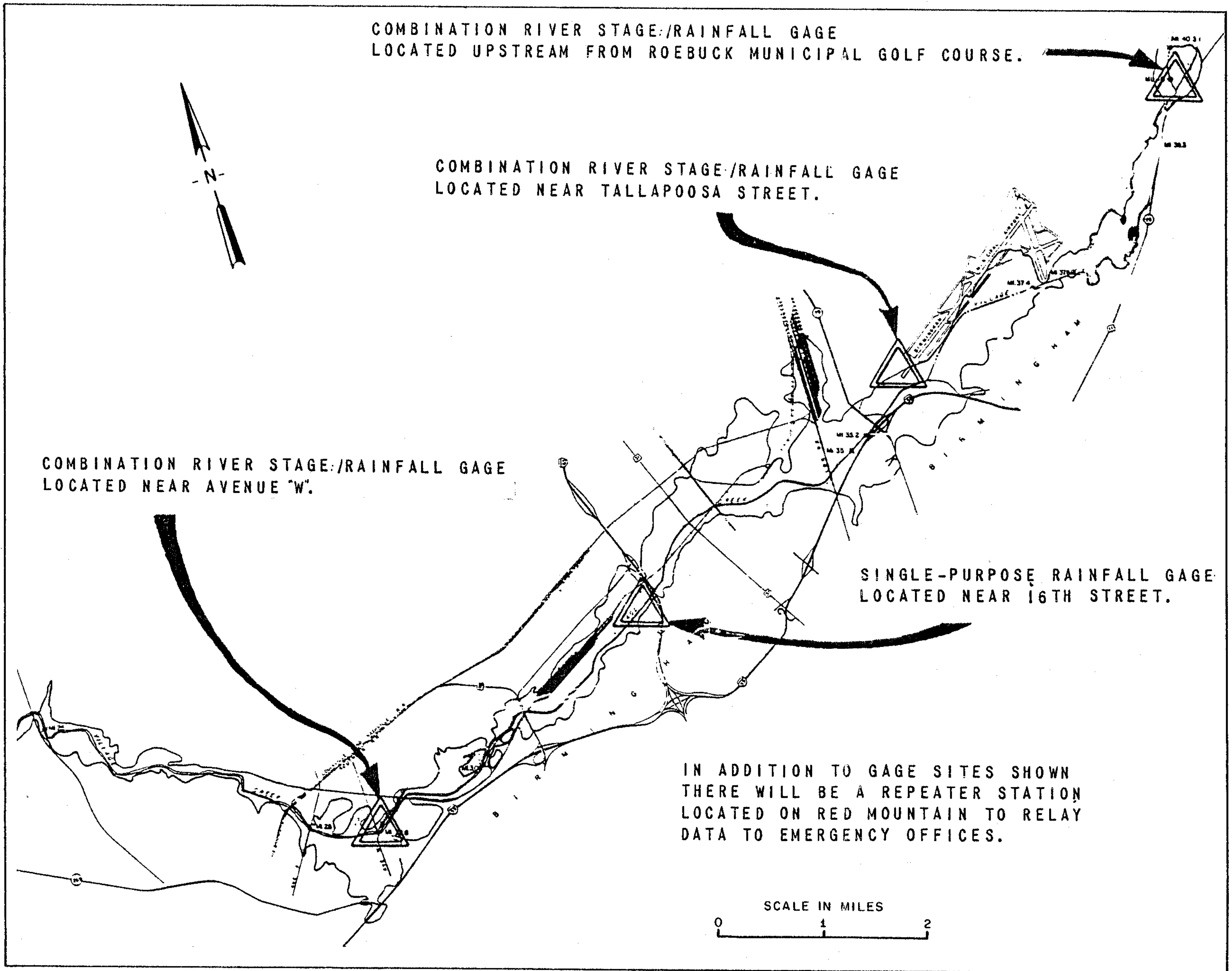

Figure 6 Locations of Automated Gages

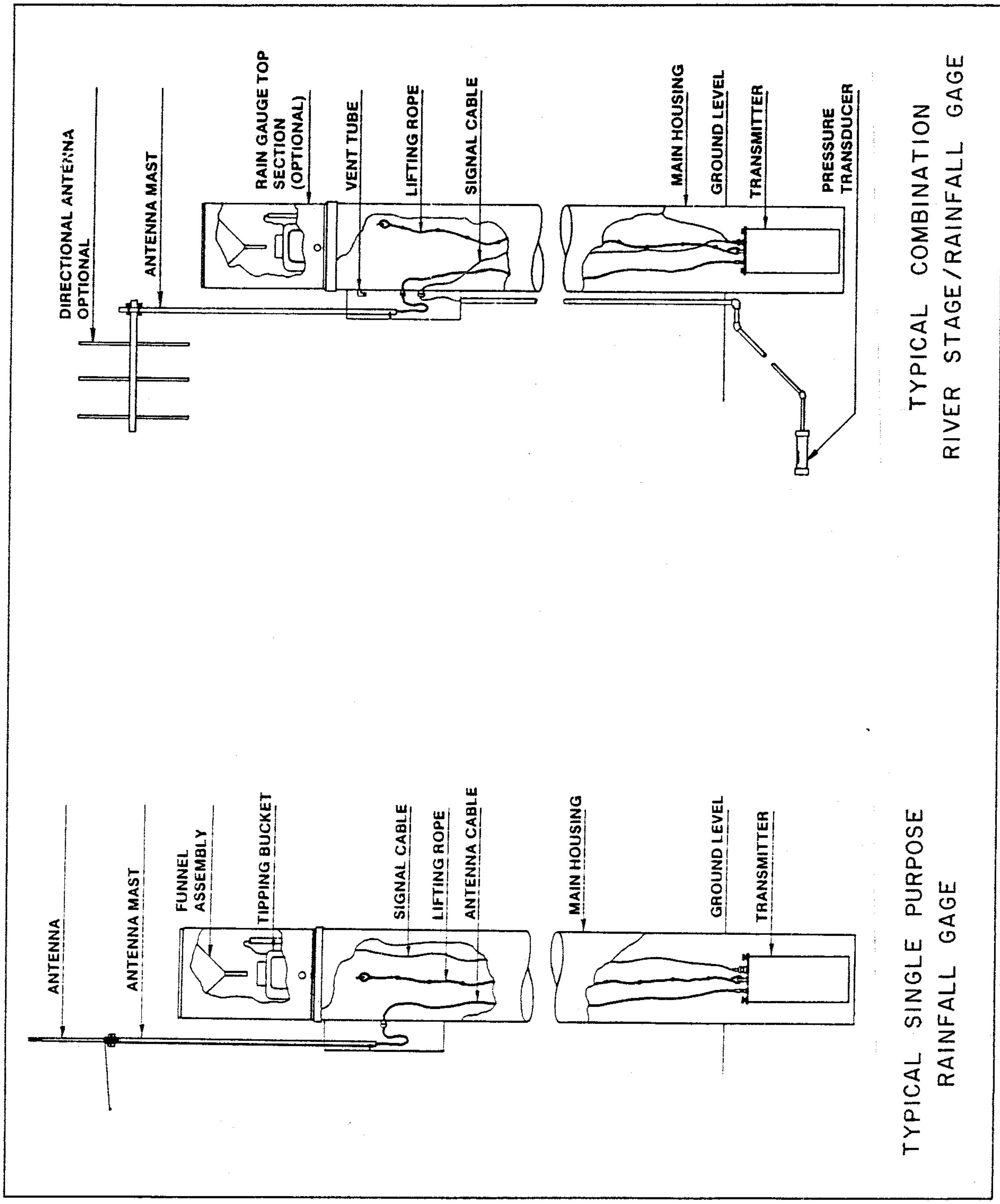

Figure 7 Typical Automated Gages

an alarm will sound alerting personnel in the EMC. There is an option for the computer to automatically call key persons whenever certain parameters are met. With the ALERT package providing information on areas inundated or expected to be inundated, emergency personnel will be able to make informed decisions and respond quickly.

Memorandum of Understanding

Now that several vendors are marketing flood warning equipment, the actual installation of a system has been greatly simplified. Some of these vendors advertise complete packages and installation. However, the long-term operation and maintenance of any automated flood warning system may prove to be a much greater challenge than the initial installation. In addition to the O&M needs for the system, there must be a local plan-of-action or contingency plan to be implemented when conditions dictate the need. It should be obvious that the actual human and physical response is as important as any warning.

Because of the need for long-term maintenance and a contingency plan, the Mobile District felt that any federal investment in the flood warning system must be protected by written agreements with the local sponsors. For the Village Creek project there are two such agreements. A Memorandum of Understanding (MOU) defines the needs for proper long-term operation and maintenance of the system along with assurance that local funding will be available for this purpose and there is a contingency plan delineating the actions to be taken by the locals during an emergency. City and Civil Defense offices have existing Disaster Assistance Plans and the contingency plan for flood warnings has been merged into that existing plan. In general, this contingency plan spells out which agencies will respond and what their responsibilities are. The following outline gives the format and table of contents for the Disaster Assistance Plan.

CONTINGENCY PLAN

PURPOSE

ORGANIZATION

DIRECTION AND CONTROL

OPERATIONAL RESPONSIBILITIES

Police Deptartment - Sheriff
Public Works Department
Pensions and Security
Transit Authority
Water Works Board
Emergency Medical Service
Emergency Management Agency -
Birmingham, Jefferson County
Utility Organizations
National Weather Service
Red Cross
National Guard

ADMINISTRATION AND LOGISTICS

PLAN DEVELOPMENT AND MAINTENANCE

The MOU between the Corps and the City of Birmingham is intended to insure the successful utilization of the system. A finalized MOU has not been signed by all parties as of this time, but the sample version presented in the Design Memorandum for the project is expected to furnish the basis for agreement. That sample MOU is attached for reference.

Summary

Design for the Village Creek flood warning system began with a survey of the problem area and an examination of the potential response time. Three different types of automated warning systems were developed including the more simple float-switch, custom design, and the state-of-the-art ALERT computerized instruments. The ALERT system was selected in consultation with officials of the City of Birmingham.

After selection of the ALERT system, it was necessary to develop a formal understanding between the Corps and the local sponsor (City of Birmingham). This understanding insures that both funding and manpower will be available for long-term operation and maintenance of the system. It further provides general details of actions to be taken during a flood event and defines the responsible authorities. It is expected that this warning system may provide emergency personnel with from 2 to 8 hours of preparation and response time during a major flood.

SAMPLE

MEMORANDUM OF UNDERSTANDING

FOR JOINT SPONSORED

AUTOMATED FLOOD WARNING SYSTEM

This Memorandum of Understanding, between the U. S. Army Corps of Engineers and the City of Birmingham, is undertaken for the purpose of defining a mutual assistance program designed to develop an Automated Flood Warning System for the Village Creek area.

1. Nature of Agreement:

The Flood Warning System for Village Creek is being implemented in conjuntion with a comprehensive flood-control project for that area. This project, which includes plans for both structural and nonstructural improvements, is a joint involvement between the Corps of Engineers and the City of Birmingham. The Flood Warning System utilizes state-of-the-art techniques that can be incorporated into an operational flood warning program. The overall concept calls for Federal and local cooperation.

2. Involvement of the National Weather Service:

An active involvement of the National Weather Service is essential to the successful completion and utilization of any automated flood warning system. For this reason it is necessary that the City of Birmingham and the National Weather Service complete a separate memorandum of understanding defining the mission and responsibilities that each will accept. Items to be included in such a memorandum of understanding are:

a. Cooperation in identifying specific site and equipment needs.

b. Mutual agreement of necessary standards for the flood warning system including gage sites and design criteria used by the Corps of Engineers.

c. Training and communications.

d. Methods of sharing data and issuing flood warnings to the public.

e. Other items of mutual concern.

The Corps of Engineers will continue to maintain its close association and cooperation with the National Weather Service in addition to the City of Birmingham's memorandum of understanding with that agency.

3. <u>Responsibility of the Corps of Engineers</u>:

a. Design and provide for installation of the flood warning system in consultation with the City of Birmingham.

b. Ensure that software is adequate for the proposed flood warning plan.

c. Assist in training personnel.

d. Cooperate with the City of Birmingham and the National Weather Service in selection of sites, equipment, and standards.

4. <u>Responsibilities of the City of Birmingham</u>:

a. Consult with the Corps of Engineers and the National Weather Service to ensure that any flood warning system is adequate and proper for the needs.

b. Ensure that adequate personnel are trained and assigned to the project.

c. Provide funds to the budget for maintenance of the system.

d. Provide necessary land for location of gaging and rainfall stations, as well as office space within the Emergency Management organization for the base station equipment.

e. Implement a memorandum of understanding with the National Weather Service to define the working relationship between the city and that agency.

f. Provide cost sharing funds with the Corps of Engineers for initial installation based on a mutually agreeable formula.

g. Develop a comprehensive "contingency plan" to fully delineate the City's planned response and objectives during a major flood event.

FLOOD PREPAREDNESS PLANNING FOR THE PASSAIC RIVER BASIN

by ROBERT A. PIETROWSKY[1]

INTRODUCTION

Flooding within the Passaic River Basin has been characterized as the most serious unsolved flood problem on the east coast of the United States. This small, complex and highly populated watershed experiences expected annual flood damages in excess of 80 million dollars a year (October 1985 price level). Although existing local and regional preparedness systems provide flood warning and response capability, the warnings are not always timely, accurate, or reliable, factors which limit their effectiveness.

The need for an improved flood warning - response system was dramatically highlighted during the record flooding of April 5-7 1984. During this storm four counties in northern New Jersey were declared Federal disaster areas. Flood damages exceeded $350 million and four people were drowned. The extensive flooding in the Central Passaic Basin exceeded by far any flooding in the memory of local flood disaster coordinators.

As part of the Corps of Engineers Passaic River Basin (PRB) Study, an investigation was made of the feasibility of implementing improvements to the existing preparedness system. The PRB study was authorized in the Water Resources Development Act of 1976. Among several Congressional mandates that the Corps received as direction for the conduct of the study was one that specified that early warning systems be considered.

This study resulted in a recommended plan consisting of a combination of flood warning improvements and response enhancements costing an estimated $675,000. The flood warning improvements include tributary flash flood warning systems, additional reporting rain and stream gages in conjunction with micro computers, remote terminals and tone alert radios. The response enhancements include stage-inundation maps, updated and coordinated county/municipal response plans, periodic flood response exercises and public education. The study included cooperative efforts between the Corps of Engineers, National Weather Service (NWS), U.S. Geogological Survey (USGS), Federal Emergency Management Agency (FEMA), and the Basin States of New Jersey and New York. The project is being implemented under the Corps of Engineers Small Project Authority, Section 205 of the Flood Control Act of 1948. This authority was selected because of the low Federal first cost and the significantly shorter implementation period required.

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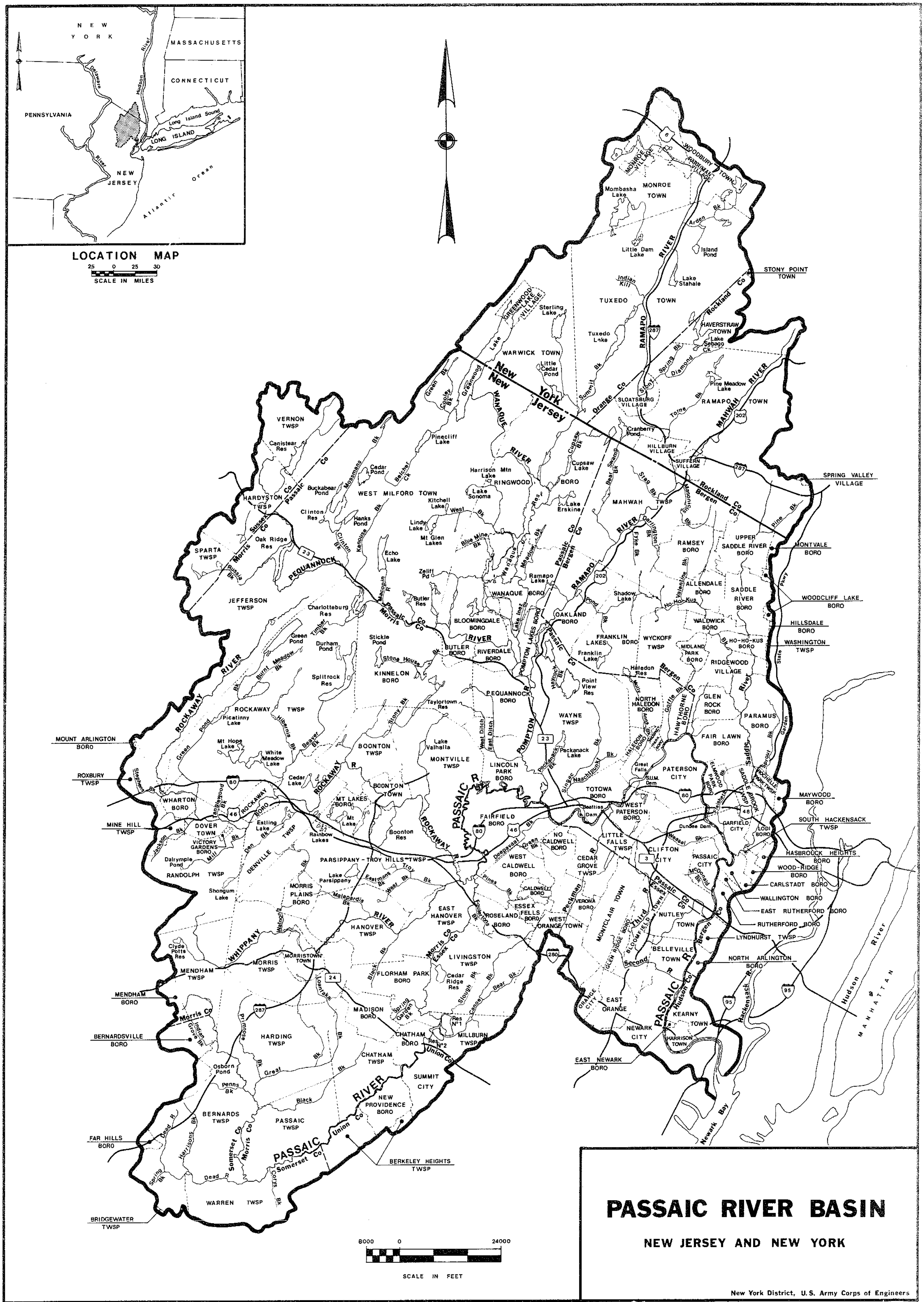
[1] Assistant Chief, Passaic River Basin and Special Studies Branch, Planning Division, New York District Corps of Engineers


PASSAIC RIVER BASIN
NEW JERSEY AND NEW YORK
New York District, U.S. Army Corps of Engineers
LOCATION MAP
SCALE IN MILES
SCALE IN FEET
NEW YORK
MASSACHUSETTS
CONNECTICUT
PENNSYLVANIA
NEW JERSEY
LONG ISLAND
Long Island Sound
Atlantic Ocean
New York
New Jersey
PASSAIC RIVER
ROCKAWAY RIVER
RAMAPO RIVER
WANAQUE RIVER
PEQUANNOCK RIVER
POMPTON R
WHIPPANY RIVER
MAHWAH RIVER
Hudson River
MANHATTAN
Newark Bay
WEST MILFORD TOWN
WARWICK TOWN
TUXEDO TOWN
MONROE TOWN
RAMAPO TOWN
PATERSON CITY
NEWARK CITY
KEARNY TOWN
MORRIS TWSP
LIVINGSTON TWSP
WAYNE TWSP
ROCKAWAY TWSP
PARSIPPANY - TROY HILLS TWSP

These recommendations raised several policy issues revolving around the degree to which the Corps of Engineers should be involved in the planning and implementation of a preparedness project which is not specifically part of an overall flood damage reduction plan. A unique set of circumstances served to offset some of the policy concerns of higher authority. These were: a ripe political climate involving the formulation of the Water Resources Development Act (W.R.D.A.) of 1986; strong non-Federal support of the project as a result of the severe 1984 flood; and the specific Congressional mandate on including early warning systems in the Passaic River Phase I study. The Local Cooperation Agreement for the project was signed and the project authorized for implementation on October 30, 1986.

BASIN DESCRIPTION

The Passaic River Basin is a 935 square mile watershed, located in the States of New Jersey and New York in the Greater New York City Metropolitan Area. Figure 1 is a map of the Passaic River Basin. The Basin is roughly elliptical in shape, 26 miles wide and 56 miles in length, and encompasses 787 square miles (84%) in New Jersey, and 148 square miles (16%) in New York. The Basin has a wide variety of features ranging from heavily wooded, mountainous rural areas, to agricultural and suburban lowlands relieved by rolling hills, to densely populated, highly industrialized urban concentrations. Occupying about 10.5% of the area of New Jersey, the Passaic River Basin contains significant portions of Bergen, Essex, Morris and Passaic Counties, and lesser portions of Hudson, Somerset, Sussex and Union Counties. Based on the 1980 Census, it is estimated that the Basin's population was over 2 million, roughly one-quarter of the State's total population, including 40% of the population of Newark, the State's largest city, and all of Paterson, the third largest.

In New York State, the Basin occupies parts of Orange and Rockland Counties, and has an estimated 1980 population of more than 52,000.

The main stem Passaic River rises in Mendham Township, Morris County, N.J. and empties into Newark Bay at Newark, N.J. Its eight major tributaries include the Third, Saddle, Pompton, Ramapo, Pequannock, Wanaque, Rockaway and Whippany Rivers.

POLITICAL DIVISIONS

There are many levels of political jurisdiction which have an impact on water resources planning in the Passaic River Basin. The Basin includes portions of two states, 10 counties, and 132 municipalities. There are eight United States

Congressional Districts in New Jersey and one in New York. Significantly, one of New Jersey's Congressman, Robert A. Roe, is the Chairman of the House Committee on Public Works and Transportation's Subcommittee on Water Resources. He is one of the chief architects of the 1986 W.R.D.A.

PLANNING SETTING

The Passaic Basin includes portions of the most densely developed metropolitan area in the country, and its flooding has often been characterized as politically unsolvable. The Basin's floodplains include nearly 48,000 residences and places of business. Flooding in the Basin has been studied at both the state and Federal level since before the turn of the century. From 1900 to 1940, the State of New Jersey produced eight major reports containing a variety of recommendations.

Corps of Engineers involvement in Passaic River planning was first authorized in the Flood Control Acts of 1936. Since then, reports recommending plans of action were issued in 1939, 1948, 1962, 1969, 1972 and 1973. None of these recommendations were ever implemented.

Planning to solve the water problems of the Passaic River Basin has been wrought with controversy and indecision. Public opposition based on the concerns of municipalities and various other interests throughout the Basin has prevented the implementation of any of the six previous plans. This opposition was based on several factors, including: the use of the Central Passaic River floodplain to protect Lower Passaic River damage areas; extensive structural measures, such as dams, levess and floodwalls; and the vast amounts of land required for implementation. Other concerns were based on environmental, economic and social factors. As a result of this opposition the people of the Passaic River continue to be plagued by frequent and severe flooding.

The Congress recognized the urgent need for flood control with the authorization of the Passaic River Basin Study in the Water Resources Development Act of 1976. Congressional guidance included in House of Representatives Report 94-1702 (see Figure 2), directed the reformulation of an existing plan, or in effect, the development of new plans to meet the water resources needs of the people of the Passaic River Basin.

FIGURE 2 CONGRESSIONAL GUIDANCE
Extract from House Report 94-1702

PASSAIC RIVER BASIN, NEW JERSEY AND NEW YORK

The Phase I study shall include consideration of interim flood protection measures, and recommendations as to such measures are to be made to the Committee as soon as they are formulated, prior to completion of the Phase I study. Implementation of interim measures consistent with Public Law 92-500 and the National Environmental Policy Act, shall begin as soon as authorized and funded, and shall not await completion of the Phase I study.

Controversy revolves around a concern that conclusions reached by the Chief of Engineers Report of February 18, 1976, will be given priority to the exclusion of equal consideration of alternatives, and other objectives, including water management and attainment of water quality goals, pursuant to P.L. 92-500. Controversy over construction of the project emanates from many communities in Morris and Essex Counties that stand to lose substantial portions of their land to structural solutions; from conservation interests who seek non-structural solutions; from those who reject dams, dikes, and levees in their communities; from those who believe other forms of construction such as a diversion tunnel or a system of tunnels addressing the needs of the entire basin should be reevaluated; from those who believe water supply objectives should be met together with flood control.

In the Water Resources Development Act of 1974, the Congress adopted a new two-step authorization procedure for projects such as the Passaic River Basin project. The reasons for this new procedure, and a description of the items to be included in Phase I advanced engineering and design, are set forth in House Report 93-541 which accompanied H.R. 10203, and repeated in the introductory material in this report. These requirements and provisions apply to the Phase I study of the Passaic River Basin project.

The Committee directs the reformulation of the plan for water management and flood control for the entire Passaic River Basin. Said plan shall include a new environmental impact statement which is the subject of public hearings and formulation of a final environmental impact statement to be submitted to the Council on Environmental Quality.

Local opposition to any plan which relies upon extensive use of dikes, dams and levees such as those proposed in previous survey reports mandates that the following alternatives or any combination thereof shall be the only ones surveyed and considered:

1. A full range of non-structural flood control alternatives to include land acquisition, flood plain mapping, flood proofing, developing early warning systems and relocation of buildings.
2. A tunnel diversion plan.
3. A system of tunnels addressing the needs of the entire basin.
4. Plans that combine local protection works where locally acceptable and non-structural solutions including improvements to stream carrying capacity in accordance with difference needs in the Lower Basin and in the Central Basin.
5. Evaluation of fulfilling water supply objectives together with flood control.
6. Aquifer recharge and undergrounds storage.
7. Reservoir management in the headwaters.

Coordination with Federal, State and local agencies particularly the New Jersey Department of Environmental Protection in its efforts on flood control and management of the total water resource cycle including water supply and water quality, shall be carried out by the Corps of Engineers.

Citing local opposition to the extensive structural remedies proposed in previous plans, the Congress provided specific direction for the Passaic River Basin Study. As shown in Figure 2, the Corps of Engineers was directed to consider a specific range of flood control alternatives including, early warning systems. House Report 94-1702 also directed the consideration of interim flood protection measures and their recommendation to Congress as soon as they are formulated, even if prior to completion of the overall Study.

THE FLOOD PROBLEM

The Passaic River Basin has a long and significant history of severe flooding. The Basin's geographic location in the East Coast stormbelt, its hydrologic conditions and extensive development in the floodplain all play a role in this susceptibility to flood damages. The 1903 flood is the Flood of Record for most of the Basin, whereas the flood of March 1945 is the Flood of Record on several tributaries. The Basin also experienced flooding in 1810, 1819, 1842, 1882, 1902, 1917, 1936, 1938, 1951, 1955, and 1960. More recently, flooding occurred in 1968, 1971, 1972, 1973, in July and September 1975, 1977, 1979, March - April 1983 and in April 1984, when portions of the Basin were declared Federal Disaster Areas.

The seriousness of the flood problem is clearly evidenced when a recurrence of the October 1903 flood is considered. Under current conditions of development, an event comparable to the 1903 flood would inundate more than 20,000 structures and cause damages estimated to be over $1.5 billion.

The April 1984 flood had a significant impact on the political response to Corps of Engineers' planning efforts. This flood occurred during a period when Corps' flood damage reduction alternatives, including warning-response plans, were being reviewed by the public. In addition, the severity of the flood caught many Basin residents and local officials by surprise, despite the operation of existing warning systems. A week before, a snowstorm deposited up to 18 inches of very wet snow in the highland areas of the watershed. The subsequent flooding resulted from runoff which far exceeded rainfall due to snowmelt and thawing ground. The nature of the flooding emphasized the limitations of the existing preparedness system, particularly the warning dissemination and response phases.

EXISTING FLOOD WARNING-RESPONSE SYSTEM

An existing flood warning-response program for the Passaic River Basin was established and maintained by the National Weather Service (NWS).

Flood warning. The existing system consists of two subprograms, river stage and flash flood. River stage warnings are provided for specific points on the Basin's major streams for which the time from the start of rainfall to peak flooding is generally longer than six hours. In the Passaic River Basin river stage warnings are provided for the Passaic, lower Rockaway, lower Whippany, Pompton, Wanaque, Pequannock, Ramapo, and Saddle Rivers.

Area-wide flash flood warnings are provided where damaging floods can occur very rapidly, usually in less than six hours, and frequently within a few hours of the beginning of rainfall. The upper portions of the Ramapo, Rockaway and Whippany Rivers, Molly Ann's Brook, and the Second and Third Rivers are subject to flash flooding. In addition, flash flood areas are subject to backwater flooding in their lower reaches. River stages along the lower reaches of the Passaic, Second, Third, and Saddle Rivers are also affected by tidal events caused by hurricane or northeaster type storm surges occurring independently, or coincidentally with fluvial events.

1) River Stage Program. The Passaic Basin is served by the NWS Philadelphia Hydrologic Service Area Office with hydrologic technical support and guidance from the Harrisburg Mid-Atlantic River Forecast Center. Rainfall data and river gage readings are assembled by the Philadelphia Hydrologic Service Area Office, and sent to the Forecast Center (see Figure 3). Using gage readings and meteorological data, the Mid-Atlantic River Forecast Center hydrologists prepare flood forecasts and transmit them to the Philadelphia Hydrologic Service Area Office. The Hydrologic Service Area Office issues the forecasts and warnings to Federal and State emergency management agencies, and to the news media for public dissemination. Counties and municipalities generally receive warnings of potential flooding from police teletype or weather radio.

2) Flash Flood Program. Unlike major river flooding, the specific locations, times, and stages of flash flooding in the Basin are difficult to predict. As a result, flash flood forecasts and warnings are currently provided for generalized areas ranging in size from subbasins (e.g. Saddle River area) to broad geographical sections of the State (e.g. northeastern New Jersey). The forecasts are also generalized (i.e. major, moderate, or minor flooding), rather than quantified.

RIVER FLOOD FORECAST SERVICE

(Passaic River, Saddle River, Pompton River, Ramopo River, Pequannock River, Wanaque River, and Rockaway River)

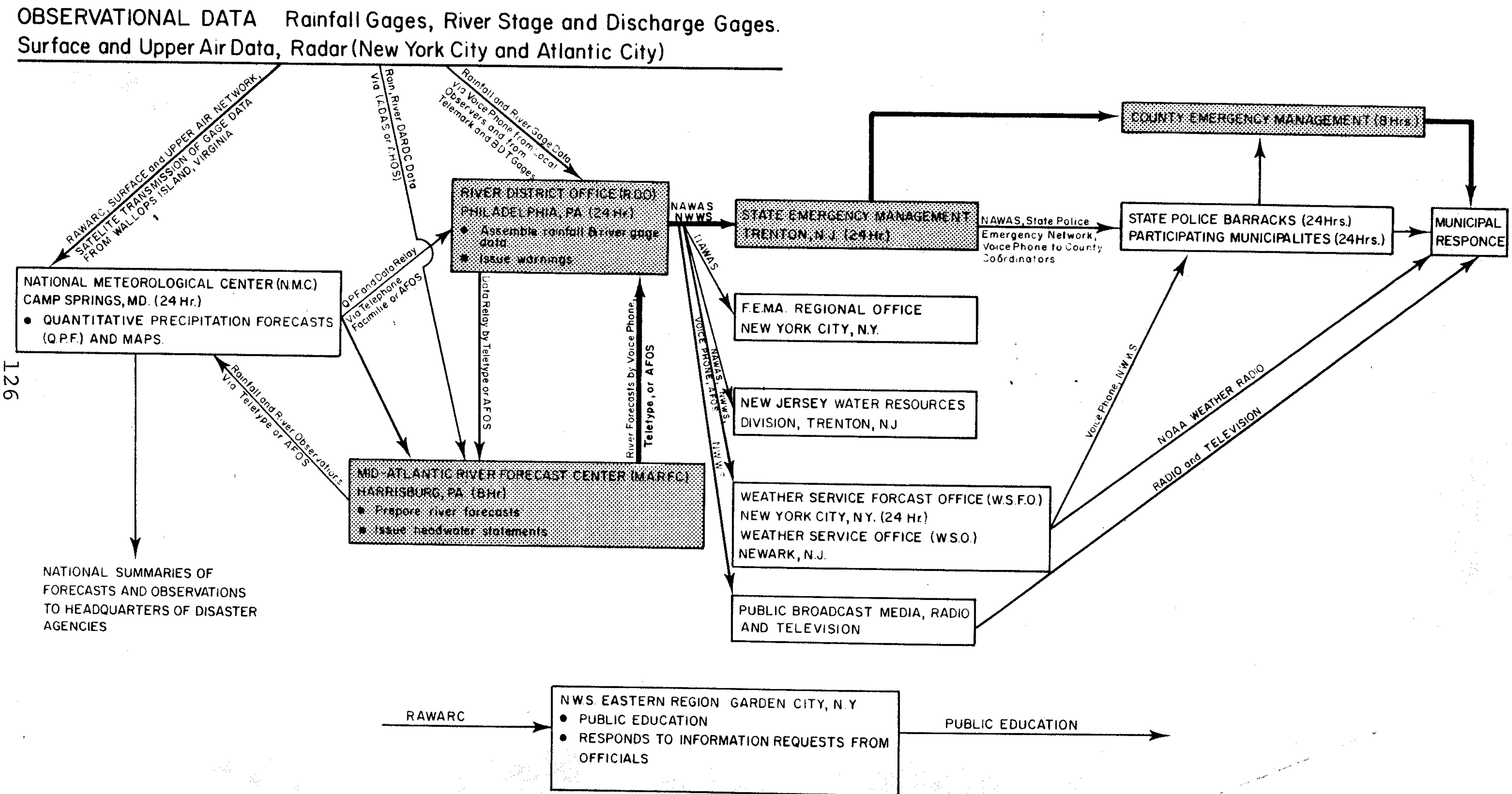


FIGURE 3

FLASH FLOOD WARNING SERVICE

OBSERVATIONAL DATA   Rainfall Gages, River Stage and Discharge Gages.
Surface and Upper Air Data, Radar (New York City and Atlantic City)

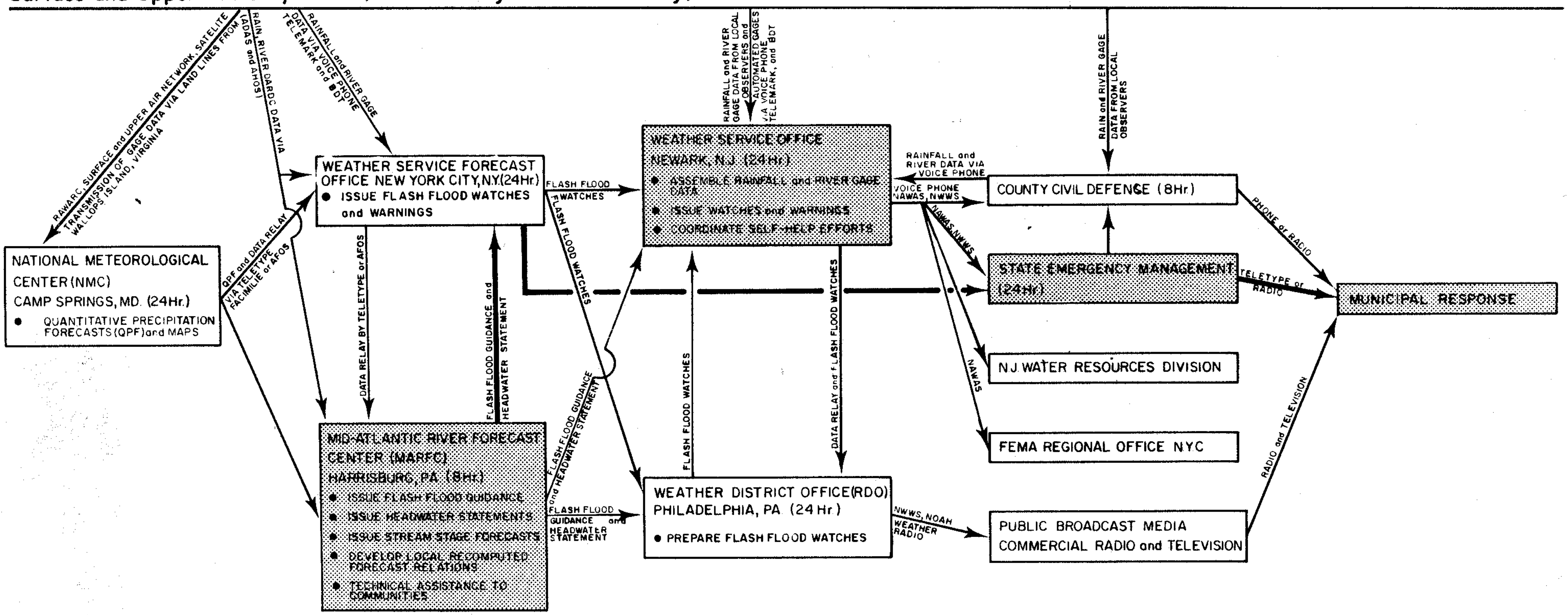


FIGURE 4

The flash flood data collection process begins with the assembly of meteorological information by the Mid-Atlantic River Forecast Center (see Figure 4). With this information the Forecast Center prepares flash flood guidance (three-hour rainfall amounts needed to cause minor flooding) which is transmitted daily to the Weather Service New York City Forecast Office. In the case of locally operated flash flood systems, the Mid-Atlantic River Forecast Center supplies the counties with a flash flood "index" twice weekly. When conditions in northern New Jersey are conducive to flash flooding, the New York City Office issues a flash flood "watch" which is transmitted to the local Weather Service Office in Newark, N.J. for further dissemination. Flash flood watches are usually valid for periods of 12 hours or less. If rainfall actually commences and flooding occurs or is imminent, a flash flood "warning" is issued by the Weather Service Office. Flash flood warnings are usually issued for periods of less than four hours.

In addition, the NWS has provided equipment and training to communities on small streams whereby the forecasting and warning can be done directly by County Emergency Management Coordinators. Bergen and Morris Counties have established local flash flood warning systems, which consist of rain gage observers with specific emergency reporting responsibilities.

Flood Response. In the Passaic River Basin, implementation of the response phase of flood preparedness rests primarily with the municipality affected by the flood event. All municipalities in the Basin have the responsibility to coordinate, direct and augment all municipal emergency services in order to cope more effectively with situations resulting from a flood disaster. Each municipality is also responsible for the procurement, distribution and use of all resources within municipal limits necessary to cope with such disaster.

Such responsibility is typically administered by a municipal Emergency Management Coordinator who has the authority to enforce the planning, coordinating and the conduct of response measures in the municipality. Each Passaic River Basin municipality has a Emergency Management Coordinator, and virtually all have some form emergency preparedness. However, for the most part these are plans which emphasize response to nuclear attack. Additionally, most of the plans are not current. The New Jersey Office of Emergency Management has approved the Emergency Operations Plans of only 10 of 80 floodplain municipalities in the Basin. This does not mean, however, that municipalities that do not have written flood preparedness plans lack a response capability. Rather, procedures and actions taken for flood emergencies have evolved from practical experience and good judgement.

The role of counties in flood emergency response is the coordination of the most effective utilization of local and county resources among municipalities in need and to provide a link between municipalities and the resources of the State.

The State of New Jersey provides a variety of resources and services to assist in the emergency response effort. The State is part of the Federal communications net for the distribution of flood warnings. Additionally, through the National Guard and State Police, personnel, equipment and supplies are allocated upon request to assist the emergency response effort. The State Police also conduct emergency training programs and seminars which, while not specifically flood oriented, improve a municipality's ability to respond to a disaster. Similarly, New York State, through its Office of Disaster Preparedness, distributes flood warnings over its communications network.

STUDY APPROACH

The flood emergency preparedness study for the Passaic River Basin was aimed at determining the feasibility of implementing measures that would improve the existing system. The overall Passaic River Basin Study had already produced a wealth of technical data which proved useful to the preparedness study. This information included topographic mapping, hydrologic and and hydraulic models, flood damage surveys, a damage structure file, and computed expected annual damages. The initial focus of the flood emergency preparedness study was an examination and evaluation of the technical and operational efficiency of the existing NWS warning system, and State, county and local responses plan elements. Problems or limitations, and possible areas of improvement were identified.

Close coordination was effected with the various operational elements of NWS, FEMA and New Jersey agencies, including the Department of Environmental Protection, and the State Police. Meetings were also held with 20 county and municipal emergency management coordinators to determine the scope of local response efforts.

In the Passaic River Basin the warning phase, including flood threat recognition and flood warning dissemination, is a highly structured, highly institutionalized operation carried out on a regional basis by full time professionals usually removed from the flood scene. On the other hand, the response phase, including emergency response actions, post flood recovery and continued plan management, is mainly a municipal responsibility consisting of disaggregated programs run by individuals, often volunteers, at the disaster scene. This distinction between warning and response paralleled the implementation responsibilities of system improvements. Under Corps of

Engineers policy, warning phase improvements were determined to be within the Federal Government implementation authority, to be cost shared with local interests under current water resources policies. Response phase improvements, however, were cast as items of local cooperation to be carried out by the non-Federal sponsor along with operation and maintenance activities.

System Evaluation. The evaluation of the warning and response phases of the existing preparedness system reflected the fundamental difference between each phase. The warning phase evaluation was based on criteria including the timeliness, accuracy and reliability of the warning; while the response phase was evaluated on more qualitative terms (is the system present?, complete?, etc.). National Weather Service personnel and local Emergency Management Coordinators were fully involved in the evaluation process and played a significant role in identifying the problems in the existing system.

The problems identified with the river stage and flash flood warning phases are listed in Tables 1 and 2, respectively, while limitations in the response phase are presented in Table 3. The major timeliness limitation identified was the flash flood warning system. For flash floods the gages could not be interrogated in a timely manner so only general qualitative advisories were issued. For the river stage program, the distribution of precipitation gages was not sufficient to achieve the accuracy standards desired by the National Weather Service. Large gaps in the location of precipitation gages could allow local storms to pass through the Basin undetected. The existing network included 18 precipitation gages and 18 stream gages. Ten of each type were automated. Adequate funds and staffing were not available to provide the rigorous maintenance required for the automatic gages to maintain their accuracy. Those gages that were manned by observers were prone to human-caused bias and error. In terms of forecast preparation, the Passaic River Basin was only one of a number of basins under the operation of the NWS's Mid-Atlantic Regional Forecast Center. During large area storms, the forecasting load sometimes exceeded staff capabilities. This lead to timeliness problems in relaying river stage warnings for the Passaic Basin. Reliability problems within the system involved the transmission of data to the forecast center and the dissemination of the warnings to local authorities and to the public.

For the response phase, the effectiveness of municipal and county responses to flooding varied widely, based on local motivation, funding, and organization. Although all Basin municipalities respond to some degree to a flood event, very few were prepared to respond fully to the event. This distinction was reflected by the almost complete lack of formal municipal and county flood preparedness plans in the Basin, highlighting the heavy reliance on personal interaction at the expense of

TABLE 1

SUMMARY OF PROBLEMS: RIVER STAGE FLOOD WARNING SYSTEM
PASSAIC RIVER BASIN

System Component	Problem
Data Collection/Transmission	1) For some sites, data collection requires too much time
	2) Insufficient gage density
	3) Insufficient gage maintenance/gage bias
	4) Potential observer reliability concerns
	5) Transmission reliability
Forecast/Warning Preparation	1) Understaffing at the NWS Forecast Center
	2) Long time periods required for preparation
	3) Insufficient forecast points
	4) Potential unreliability caused by data transmission system and staff schedules
Warning Dissemination	1) Occasionally not able to provide enough time for response by public
	2) No site-specific identification of impacted areas
	3) Many residents may not receive radio and TV warnings
	4) No local backup systems for warning dissemination with reliable ties to the forecast center
	5) Many residents may not receive accurate warnings

TABLE 2

SUMMARY OF PROBLEMS: FLASH FLOOD WARNING SYSTEM

System Component	Problem
Data Collection/Transmission	1) Existing system requires too much time to interrogate observers and gages
	2) Insufficient gage density
	3) Potential gage/observer bias
	4) Potential disruption of transmissions
	5) Observer motivation
Forecast/Warning Preparation	1) Timely data collection not possible
	2) Timely warning preparation not possible
	3) Input data may be unreliable
	4) No environmental evidence of impending flood
Warning Dissemination	1) Timely warning not given to public
	2) Timely warning not given to local officials
	3) Only general warnings given - not site-specific
	4) Many residents may not receive an accurate warning
	5) Warning system cannot reach all residents

TABLE 3

SUMMARY OF PROBLEMS: RESPONSE PHASE PASSAIC RIVER BASIN

Component	Problem
Assignment of Responsibility	1) Voluntary, unpaid Emergency Management Coordinators often lack authority, and familiarity and immediacy in directing flood emergency response.
	2) Duplication, as well as oversight, occurs as a result of lack of current emergency plans.
	3) Municipal flood response activities are usually carried out independent of county activities.
Procedures and Decision-Making	1) Specific implementing procedures for flood emergencies are usually lacking. Although virtually all communities have Emergency Operations Plans, they are neither current nor flood specific.
Communications	1) Communications overload is common during flood emergencies due to lack of radio channels and personnel.
	2) Emergency Operations Centers are often too small and inadequately equipped to properly function as a communications and decision center.
Intergovernment Coordination	1) There is little information exchange between communities.
	2) Certain types of flood fighting activities undertaken in one community can adversely affect its neighbor.
Public Information	1) There are few programs to inform and educate residents about flood preparedness.

institutional response. Overall, the lack of local flood preparedness plans reflected the greater emphasis placed on the capability of the warning system with correspondingly lesser emphasis on responding to the warning. It was recognized that even the most sophisticated warning system is of little value if the warnings are not received and properly acted on, and care was taken to treat both the warning and response phases.

PLAN FORMULATION

Plan formulation was based on achieving the study objectives of reducing risks to life, property damages and social disruption. To achieve these objectives, procedural improvements to the Warning and Response Phases of the system based on the problems previously noted were recommended. Table 4 present a summary of the goals, objectives and procedural improvements associated with the formulation of preparedness plans. Enhancements to the existing system were considered at two alternative levels. First, improvements designed to expand the accuracy and reliability of the system, while minimizing technological improvements; and then, more sophisticated enhancements designed to extend the coverage of the system and to speed the timing of warnings through equipment improvements. Cost estimates and economic analyses were developed for each alternative, utilizing the traditional Corps of Engineers benefit-cost method. This approach, though difficult to apply, utilized an association between forecast lead time and damage reduction in conjunction with rational assumptions regarding warning dissemination and public response. The resulting quantifiable benefits, when compared to the relatively low investment costs, emphasized the value of the system enhancements, uncertainties in the benefits analysis notwithstanding.

Alternative II, with the more sophisticated enhancement, proved to have the greater excess benefits over costs and was supported by local interests.

Recommended Plan. The recommended plan was designed to extend the coverage of the system and to reduce the time necessary for forecast preparation and warning dissemination. Table 5 summarizes the recommended improvements.

Flash flood systems with electronically automated river and precipitation gages reporting directly to emergency institutions would be provided for six Passaic River tributaries where the response time was exceeded by forecast preparation time. All precipitation and stream gages would be automated to avoid local observer bias and to speed the delivery of data. Event reporting stream and rain gages would transmit radio signals to six county micro-computer sites. County computers would receive data, and then automatically dial selected remote terminals at the municipal emergency headquarters and transmit

TABLE 4

ENHANCEMENTS TO FLOOD WARNING
AND EMERGENCY PREPAREDNESS SYSTEM
PASSAIC RIVER BASIN

Problem & Opportunity (ie. Goal)

Reduction of Loss of Life, Property, and Social Disruption Associated with Flooding

Objectives

1. Implement a Timely/Reliable/Accurate Warning System for Areas throughout the Passaic Basin subject to Floods and Flash Floods.

2. Develop Public Information Programs to Ensure Effective Flood Emergency Response Activities.

3. Orient all affected public/private agencies from local through federal level to achieve a universally clear sense of purpose, direction, responsibility, and role for all parties involved during an impending flood event.

Procedural Improvements

Warning Phase	Response Phase
1. Accelerate data collection rates.	1. Develop Comprehensive flood response procedures at the local level for all major damage center communities.
2. Improve the spatial accuracy of data collection.	2. Develop an expanded public information/education program
3. Expand the system to cover areas not yet included in the system.	3. Develop a local capability to respond to the more frequent flood events with minimal dependence on outside assistance.
4. Accelerate the speed of warning release, especially in flash flood areas.	

warnings, forecasts, flood guidance and other information. Response enhancements included stage-inundation maps, updated and coordinated county-municipal response plans, periodic flood response exercises, and public education.

The project, with an estimated cost of $675,000 (October 1985), was recommended for implementation under the Corps' Small Project Authority under Section 205 of the Flood Control Act of 1948. This authority was utilized because of the project's low Federal First Cost and the significantly shorter implementation period required because specific Congressional authorization is not be needed. This final Detailed Project Study was completed by the New York District Corps of Engineers in June 1984. The report was approved as a basis for preparing plans and specifications by the Corps' Office of the Chief of Engineers in September 1984. During this period of review several significant policy issues were raised by higher authority.

POLICY ISSUES

The recommendation for Corps of Engineers involvement in the improvement of an existing flood preparedness system was met with some skepticism by higher authority, despite the relatively small outlay of costs required for implementation. Concerns were expressed over the long range impact such a project would have in terms of establishing a Corps of Engineers' precedent for flood emergency preparedness projects across the Nation. The central issue was the degree to which the Corps should be involved in the planning and implementation of a project involving no construction.

During the review of the Detailed Project Study some planners questioned the wisdom of such projects, arguing that flood warning and response are, at the non-Federal level, most intimately related to local police powers and responsibilities, and at the Federal level basic flood warning responsibilities are vested with the National Weather Service. They believed that the study recommendations should be for Congressional authorization of a project to be implemented by the National Weather Service, the Federal Emergency Management Agency and U.S.G.S., those Federal agencies involved in the existing warning system.

However, the project recommendation could be strongly supported by citing HR 94-1702. This Congressional guidance specifically directed that the Corps consider early warning systems along with other nonstructural measures. In this context, the recommended project is facilitating the improvement of a preparedness system which is a critical element of a comprehensive solution to Passaic Basin flooding. The other Federal agencies expressed their inability to implement the project, and fully supported the Corps of Engineers' recommendation.

TABLE 5

RECOMMENDED ENHANCEMENTS
FLOOD EMERGENCY PREPAREDNESS PROJECT
PASSAIC RIVER BASIN

Warning Phase

- Additional and Automated Rain and Stream Gages
- Micro Computers
- Remote Terminals
- Tone Alert Radios

Response Phase

- Stage-Inundation Maps
- Updated/Coordinated Local Response Plans
- Periodic Flood Response Exercises
- Public Education

Some reviewers also felt that Corps implementation of flood emergency preparedness projects should be limited to cases where such elements are part of a comprehensive construction project. Corps of Engineers policy guidance, included in ER 1105-2-20, was cited as supporting the position that flood warning equipment is a nonstructural measure suitable only as part of an overall Corps flood damage reduction plan, not as a project in and of itself. It was also recognized, however, that how this preparedness project fits into the planning for the overall Passaic River Basin should not be overlooked. Although the project was recommended under the Small Project Authority, it can be viewed as a part of an overall project for the Passaic River Basin that is being implemented earlier than the rest of the comprehensive plan. Although the implementation of the overall project is not certain, the flood preparedness project was demonstrated to be compatible with such a project, and would serve to provide a degree of relief until the comprehensive solution can be implemented, some 15-20 years in the future.

Concerns were also expressed that the adoption of an innovative Federal project under one of the Chief of Engineers continuing authorities is inappropriate. It was pointed out that there is no Congressionally-authorized precedent for a Corps project consisting solely of flood warning measures. It was argued, therefore, that it would not be proper for the Chief of Engineers to implement this project without specific Congressional authorization.

It was also true, however, that the Congressional Guidance for the Passaic River Study specified that recommendations for interim projects be made as soon as they are formulated, prior to the completion of the overall PRB Study. It was noted that many times a Congressionally authorized feasibility study has concluded that existing Corps authorities are sufficient to permit a solution to be implemented. Certainly, in this case the use of the Small Project Authority clearly serves to expedite project implementation. To process the recommendation formally to the Congress for authorization, in lieu of utilizing an existing Corps authority, would not have been responsive to the Congressional guidance to implement interim projects for the Passaic River Basin as soon as possible.

STATUS OF PROJECT

The preparation of plans and specifications for the project were initiated in 1985. The State of New Jersey and the other Federal agencies, particularly the National Weather Service and U.S.G.S. played major roles in the development of the project specifications. Numerous equipment and procedural improvements were suggested and included in order to further enhance the efficiency of the project. The New Jersey officials also continued to work with County and municipal emergency coordinators to upgrade the response phase of the project.

In 1986, the report was transmitted to the Secretary of the Army for final review. During this period, representatives of the State of New Jersey and the State's Congressional delegation actively supported the project. Congressman Roe, in particular, expressed significant interest in the project. Because of this activity the Secretary of the Army's decision to authorize the Flood Warning-Response Project was a highly visible one. Plans and specifications were completed in 1986, and on October 30, 1986 the Local Cooperation Agreement for the project was signed by the State of New Jersey and the Secretary of the Army.

CONCLUSIONS

The Corps' role in formulating and implementing improvements to the flood warning-response system for the Passaic River Basin was unique because of the Congressional guidance for the study. Although the planning of flood preparedness projects is not traditionally within the purview or expertise of the Corps of Engineers, this study demonstrated that a cooperative effort between Federal agencies with common interests can succeed when flexible and innovative implementation approaches are explored. The study documented the economic feasibility of flood warning-response improvements, and the use of the Small Project Authority enhanced the credibility of the Corps of Engineers by demonstrating that we can respond to public needs in a timely manner.

With a time-frame for a typical Corps of Engineers' civil project of 20 years or more, the consideration of flood warning-response alternatives as interim projects is appropriate as an element of providing flood relief within the context of Corps authorities.

The beneficial effects of such study efforts also go beyond the Federal level. The study also served as the catalyst for local, county and State agencies to upgrade and unify their reponse plans.

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FLOOD DAMAGE REDUCTION SURVEYS: SELF-HELP PROGRAM

by George Nicholas Fach, Jr.[1]

Introduction

The Flood Plain Management Services Program is the Corps of Engineers' means of providing assistance to others on flood and flood plain related matters. In the Baltimore District, flood damage reduction surveys are conducted for businesses and industries to provide advice on self-help actions to reduce flood losses. Surveys are conducted by an interagency team of representatives from various federal, state, and regional agencies. Collectively, the team possesses expertise in a full range of flood damage reduction measures including structural and nonstructural improvements, floodproofing, emergency preparedness, evacuation, flood warning, and flood insurance.

Since 1979, thirty-one surveys have been conducted for various types of facilities including metal and textile product manufacturers, a food processing plant, aircraft manufacturing and repair facilities, industrial parks, a multi-tenant shopping center, and wastewater treatment plants. In every case, the team recommended some form of action relating to flood warning and emergency response. To varying degrees, these recommendations have been implemented and proven to be successful. This paper will examine some of the typical flood warning-response actions recommended and will review the results of several follow-up activities to determine the degree of implementation and effectiveness of these actions. The author will also comment as to the conditions which have influenced the degree of implementation and success of such actions.

Flood Damage Reduction Surveys

Authority and Purpose. Flood damage reduction surveys for businesses and industries are performed under the Corps' Flood Plain Management Services Program which is authorized by Section 206 of the Flood Control Act of 1960. The objective of the program is to use Corps' expertise in planning and technical assistance to assist others on flood and flood plain related matters. The purpose of flood damage reduction surveys is to provide advice on self-help measures that can be implemented to reduce flood losses. Flood prone businesses and industries are often faced with the choice of doing something about the problem, ceasing operation, or relocating. Flood damage reduction surveys are an important activity because they help local governments achieve their goals of economic stability and flood plain management.

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Evolution of the Concept. The Baltimore District became involved in flood damage reduction surveys as a result of its participation in a seminar entitled, Flood Warning and Flood Proofing Seminar For Industry, held on 16-17 April 1979 in Williamsport, Pennsylvania. The seminar was co-sponsored by the SEDA-Council of Governments (a regional economic development organization) and the Lycoming County Planning Commission. The purpose of the seminar was to disseminate information on flood damage reduction techniques through presentations by technical experts from the private and public sectors and by examining the highly successful actions taken by Sprout-Waldron, a manufacturing company located in Muncy, Pennsylvania. After suffering severe losses as a result of the June 1972 Tropical Storm "Agnes" flood, Sprout Waldron developed a flood warning-response program that significantly reduced its losses from another major flood that occurred in 1975. After the seminar, several representatives of business and industry requested assistance in developing similar programs.

The Baltimore District along with several other agencies recognized that most businesses and industries do not have the expertise to develop flood damage reduction programs by themselves and that the agencies could play a vital role in providing the needed assistance. It was also realized that no one agency had the resources to address the need by itself. Therefore, an approach was conceived to work together as a team to perform surveys of individual facilities and to provide specific and reasonable recommendations that can be implemented to reduce flood losses.

Survey Team Organization. Flood damage reduction surveys are conducted by a team of representatives from different agencies and backgrounds. The agencies currently participating are: the Baltimore District, Corps of Engineers - we act as chairman and organizer of the team; Region 3 of the Federal Emergency Management Agency; the National Weather Service; the Susquehanna River Basin Commission; the Pennsylvania Departments of Community Affairs and Environmental Resources; SEDA-Council of Governments; and the Maryland Water Resources Administration. The local agency requesting assistance also participates on the team.

Team's Areas of Expertise. Through individual members, the team has expertise in a full range of flood damage reduction measures. In developing recommendations for a particular business or industry, the team will draw from the following set of flood damage reduction measures:

1) Structural flood protection - the traditional solutions including dams, levees, floodwalls, and channel modifications.

2) Floodproofing - involves modifications to the site, building, and contents to reduce susceptibility to damage.

3) Emergency preparedness - analyzing the site specific effects of flooding and developing a plan of pre-flood response and post-flood recovery actions to reduce these effects.

4) Evacuation - having the capability (i.e.; organization, manpower, and equipment) necessary to relocate damageable items to a safe location prior to a flood.

5) Flood forecast and warning - establishing the means to detect, quantify, interpret, and disseminate information about potential floods before they occur.

6) Flood insurance - does not prevent losses, but can provide financial compensation for emergency costs and unavoidable physical losses.

Together, these measures provide a comprehensive set of tools for achieving flood damage reduction.

Survey Procedures. The flood damage reduction survey process begins with a request for assistance from a state or local government agency or organization on behalf of a business or industry. The next step is to meet with the business or industry. At this time, a representative from the District and the local requesting agency meet with company representatives to determine whether they really want assistance and if a survey by the full team is warranted. On several occasions it was determined, as a result of this preliminary meeting, that the company was satisfied to make due with information (i.e.; publications on flood damage reduction) and advice furnished by the Corps representative.

When the full team is mobilized for a survey, it begins with a meeting with company officials. The purpose of this meeting is to obtain information about the nature of the business and its flood problems. Immediately following this meeting, the team will conduct an on-site inspection of the facility to see how the business operates and how it is affected by flooding. This tour of the facility is guided by company officials and provides an opportunity for team members to ask more specific questions. After the on-site inspection, the team meets to discuss ideas and formulate preliminary recommendations. Where something can not be resolved at the time of the post-survey meeting, appropriate team members are assigned to perform additional research and analysis to develop the information required to make a decision. In some cases, this has involved estimating preliminary cost and benefit data to demonstrate the economic feasibility of a particular recommendation, such as flood control improvements, floodproofing, or flood insurance.

The Baltimore District then compiles all of the information into a report. A draft report is sent to the members of the team, the local requesting agency, and the company for review. Comments are incorporated and the final report is distributed to the same entities. After the company has had time to review the team's recommendations, a follow-up meeting is held to explain them and to discuss future actions and possible sources of assistance.

The whole survey process normally takes between four and six months - from the time of the initial meeting to the follow-up meeting. The time involved on the part of the company is minimal - between two and four hours for the pre-survey meeting and tour of the facility. The Corps representative spends about one month on each survey and the other team members each spend a day or two on a typical survey.

Typical Flood Warning-Response Recommendations

Since 1979, the Baltimore District has performed 31 flood damage reduction surveys for a variety of facilities including metal and textile products manufacturers, a food processing plant, aircraft manufacturing and repair facilities, industrial parks, a shopping center, and wastewater treatment plants. For each facility surveyed, one or more recommendations were made involving flood warning-response activities. In every case, it was recommended that procedures be developed to obtain and utilize existing flood warning information. At several locations, it was recommended that local flash flood warning systems be established. Where available, additional data were developed to relate quantitative flood forecast data (i.e.; stage forecasts) to elevation or depth of flooding at the facility. For the majority of facilities, the team recommended some form of flood warning-response action (i.e.; contingent dry floodproofing measures and/or evacuation of equipment, materials, and records) and furnished additional information on the development of a response plan. The following paragraphs describe the typical recommendations of the team that relate to flood warning and response actions.

Availability and Use of Existing Flood Warning Information. Of the various facilities surveyed, there has been much diversity in the level of awareness and understanding of available flood warning information. To reinforce that flood warning is the key element in having an effective flood damage reduction plan, it is a standard recommendation that arrangements be made to obtain these data. As a primary vehicle for receiving flood warning information, it is recommended that each business or industry obtain one or more weather radios and that a radio be accessible to key decision-making personnel at all times. It is also standard practice for the National Weather Service (NWS) team representative to explain the meaning of the flood "watch" and "warning" messages and the river stage forecast procedure for the area. For planning purposes, the NWS also provides an estimate of the flood warning response time that can be expected. This information is also useful to the team as it gives them an idea of what magnitude of effort can be expended in implementing emergency response actions. This time constraint strongly influences what the team will recommend.

The team is also concerned with the local government's role in the development and dissemination of flood warning information. If local flash flood warning systems for small streams do not exist, it is recommended that NWS assistance be requested to establish them and that the business or industry become involved in the implementation and operation of the system. The team also investigates local government's emergency management organization and communications to determine whether the business or industry has been receiving timely information. The team's recommendations stress the need for the facility's decision-maker(s) to know the local emergency coordinator and to have dependable means of communication among these persons, such as two-way radio.

Additional Flood Warning Data. To assist in the development of a detailed emergency preparedness plan by the business or industry, the team has, on numerous occasions, provided additional data to relate quantitative flood forecast data (i.e.; stage forecasts) to the elevation or depth of flooding at the facility. Based on these data, company planners can conduct a vulnerability analysis to determine the effects of specific flood stages on the facility. This enables the business or industry to develop a more detailed, refined plan that is organized to take only the specific actions necessary to address the effects of the degree of flooding that is forecasted.

The following is an example of the type of data that is typically developed to relate flood stage to elevation or depth of flooding at a particular facility. The data takes the form of a curve showing the relationship between flood stage at a nearby stream gage and flood elevation or depth at the facility. A sample relationship for the Murphys Mart Plaza shopping center located near Huntingdon, Pennsylvania, is presented as Figure 1 (Baltimore District 1986). The data used to develop this relationship are contained in Table 1 (Baltimore District 1986). In this case, water surface profile data from a flood insurance study were used to determine flood elevations at the gage and the plaza for the 10-, 50-, 100-, and 500-year discharges. Knowing the elevations of the gage datum and the plaza floor, the corresponding stage at the gage and flood depth at the plaza can be determined. Such a relationship can also be constructed from flood stage and depth data obtained from historical flood events.

TABLE 1
DATA TO CORRELATE FLOOD STAGE AT HUNTINGDON, PA, GAGE AND FLOOD ELEVATION AT MURPHYS MART PLAZA

Flood Event	Elevation at Gage (NGVD)	Stage at Gage (feet) [1]	Elevation at Plaza (NGVD)	Depth at Plaza (feet) [2]
10-year	615.3	15.6	613.6	4.1
50-year	619.5	19.8	618.0	8.5
100-year	621.8	22.1	620.4	10.9
500-year	628.1	28.4	626.5	17.0

[1] Based on gage datum of 599.69 feet NGVD

[2] Based on plaza floor elevation of 609.5 feet NGVD

Flood Risk Analysis. In situations where flood frequency-elevation data are available, they have also been used to demonstrate the degree of flood hazard susceptibility in terms of the probability and risk of occurrence of different flood depths. These data express flood hazards in terms that decision-makers can relate to in determining what is an acceptable level of risk and what level warrants action to reduce susceptibility to flooding. For the following example of the Murphys Mart Plaza, refer to the data in Table 2 (Baltimore District 1986). To avoid the misconceptions created by using return interval to refer to different degrees of flood hazard, the annual exceedance probability is presented. Then, since business decisions are usually viewed in terms of some period of time over which the initial investment will yield a return, the probability of a flood occurrence over

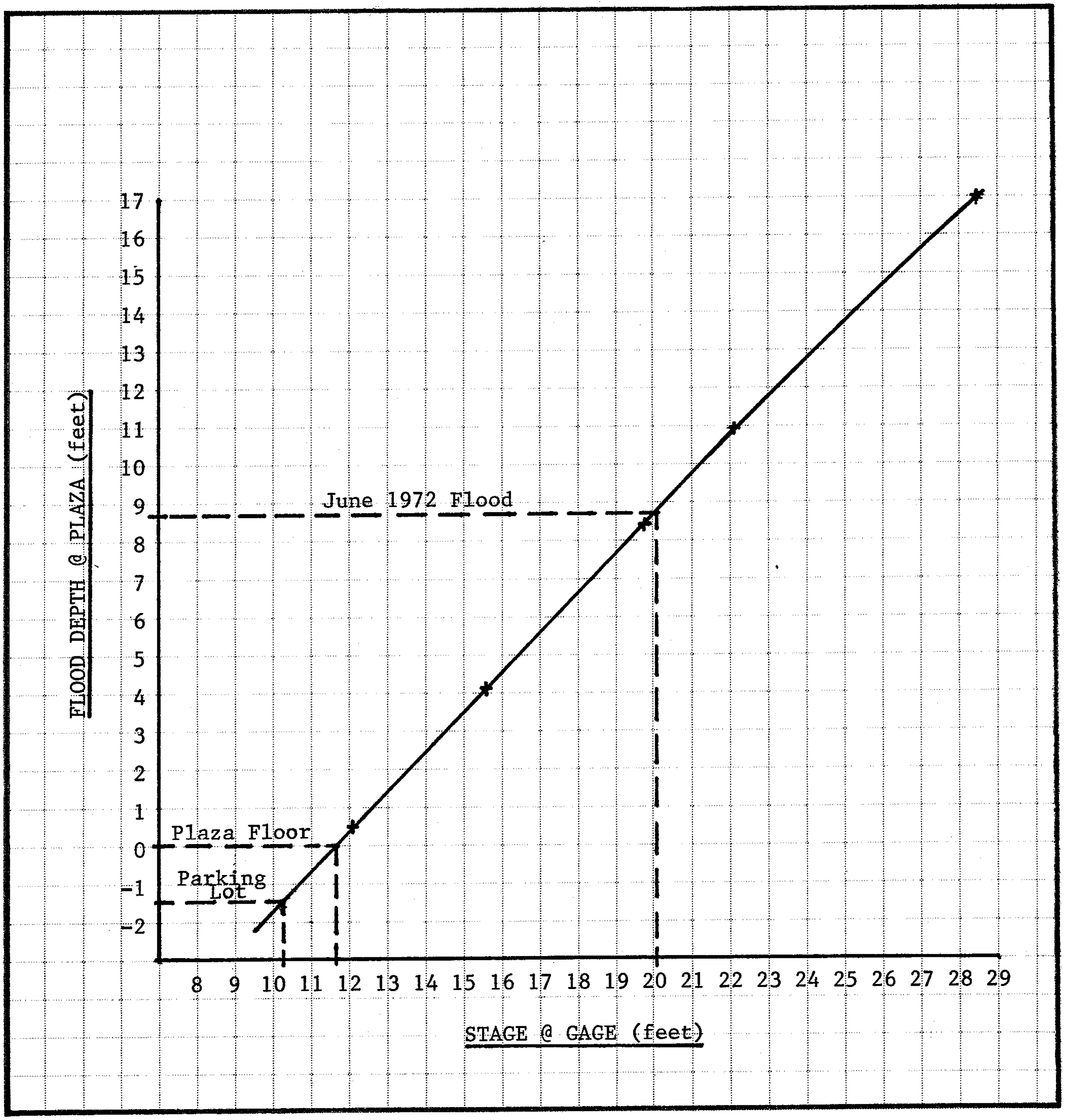

Figure 1 Relationship Between Stage at the Juniata River at Huntingdon Gage and Flood Depth at Murphys Mart Plaza

several time periods is provided. For example, if a plaza tenant planned to be at this location for a period of ten years, there is a 65.1 percent chance of having at least one flood reaching a depth of 4.1 feet. These data provide a basis for the tenant to decide whether this is an acceptable risk or whether something should be done to avoid the consequences associated with the risk. The basis for determination of risk is the following formula (Linsley 1975),

$$J = 1 - (1 - p)^N$$

where J is the probability that a flood having an annual probability of occurrence, p, will be equalled or exceeded during a period of N years.

TABLE 2
FLOOD HAZARD DATA FOR MURPHY'S MART PLAZA

Return Interval	Probability (%) Annual	5yrs	10yrs	30yrs	Elevation (ft. NGVD)	Depth at Plaza (ft)
10-yr	10.0	41.0	65.1	95.8	613.6	4.1
50-yr	2.0	9.6	18.3	45.5	618.0	8.5
100-yr	1.0	4.9	9.6	26.0	620.4	10.9
500-yr	0.2	1.0	2.0	5.8	626.5	17.0

Flood Warning-Response Actions. As indicated previously, the flood damage reduction survey team takes a comprehensive viewpoint when determining the most appropriate recommendations for each business or industry. In the category of flood warning-response actions, contingent dry floodproofing and evacuation of contents are typically recommended. Usually, the practical constraints of buildings' structural integrity and available flood warning response time dictate which of these measures is most appropriate for a given facility. Sometimes, the team has been able to recommend both measures where either would achieve a relatively high degree of flood damage reduction. In some cases, floodproofing has been the recommended response to lesser floods while evacuation is recommended for severe flooding conditions.

1) Contingent Dry Floodproofing Measures. This group of flood warning-response actions generally concerns those floodproofing measures which modify the building structure to prevent flooding of the contents. Due to the types of structures typically involved in business and industrial activities, the team's recommendations for floodproofing have been limited to actions to seal openings through which water can enter the building. Closure of openings can be accomplished either on a permanent basis or temporarily, as a flood warning-response action implemented contingent to receipt of a flood warning. Again, due to the nature of a business's operational activities, not all openings can be permanently sealed (e.g.; doors, vents, and loading docks) and

must be addressed by contingent measures.

a) Contingent floodproofing measures recommended by the team typically involve temporary closures to prevent entry of water through doors, windows, vents, and utility passages. The possible methods for sealing such openings include sand bags, removable flood shields, and inflatable pipe plugs. The choice of method and materials depends on the specific application, the amount of flood warning time available, the resources (i.e.; manpower and equipment) needed for implementation, and the cost.

b) Whenever the team recommends any type of dry floodproofing, the business or industry is advised that there is a limit to the degree of protection that can be achieved by floodproofing and that exceeding this limit can potentially result in severe damage to the structure. Along with recommendations for dry floodproofing, the team suggests that the company obtain the services of a professional engineer to determine the structural adequacy of such measures.

2) <u>Evacuation of Contents</u>. In recognition of federal disaster assistance statistics which show that the majority of the value of flood related losses are attributable to contents, the flood damage reduction survey team almost always recommends that contents be evacuated to a safe location. In business and industry, vulnerable contents include a variety of items such as equipment, records, inventory, raw materials, and finished goods. There are some special considerations to effecting the evacuation of these items in commercial and industrial business situations.

a) The type and amount of contents varies depending on the nature of the business or industry. These, and many other factors influence the development of an effective evacuation plan. In every situation where the team recommends evacuation of contents, it is suggested that the specific actions to be taken be part of the company's written emergency response plan. To maintain the high degree of efficiency needed to carry out an effective evacuation plan, company officials are urged to practice and update the plan regularly. The best way to find out if a plan will work is to try it.

b) The two most important considerations for the evacuation of contents from commercial and industrial businesses are time and resources. The amount of time available in which to carry out an evacuation will determine what can be moved. Since there may not be enough flood warning time available to evacuate all contents, it is recommended that company officials develop a list of items to be evacuated and prioritize the list in the order of evacuation. The order of items should be established based on criteria such as monetary value and difficulty to repair or replace.

c) Several suggestions have been made on how to minimize the amount of time required to complete evacuation. In the case of large, mostly durable machinery (i.e.; manufacturing), only the components that are vulnerable to flooding (i.e.; electronics) need to be evacuated. To reduce the amount of time and skilled labor needed to remove machinery components (e.g.; electric motors), they can be fitted with quick disconnecting electrical plugs and connectors. The installation of lifting eyes and use of cranes, hoists, and fork lift trucks should be considered to speed the movement of large, heavy objects. Evacuation of a large number of smaller items can be facilitated by the use of hand trucks, dollys, and containers.

d) Manpower and transportation resources are critical to having an effective evacuation plan. If the company does not have enough personnel on staff, arrangements should be made to obtain assistance through local sources such as schools or other public institutions. Also, if the company does not have the right number or type of vehicles need to transport its contents to a pre-arranged storage area, such resources should be obtained via pre-arranged agreements with local businesses.

Assessment of Program Effectiveness

Seven years and 31 surveys later, there are several indicators of the degree of success that has been realized through the flood damage reduction survey program. These include; follow-up surveys of businesses and industries to determine what actions have been taken, a documented case history of how several businesses in one community responded to a recent flood event, and the preparation and distribution of publications concerning self-help flood damage reduction.

Follow-up Surveys. Two separate follow-up surveys have been conducted to determine to what degree businesses and industries surveyed by the Baltimore District's interagency survey team have implemented the team's recommendations. One survey was conducted by District staff in February 1983 and involved a total of 12 businesses, industries, and wastewater treatment plants in the Susquehanna River Basin in Pennsylvania. A second survey was conducted in July 1984 by the City Department of Planning for six industries that had been surveyed in Baltimore, Maryland. The following paragraphs summarize the findings of these surveys as they relate to the implementation of the team's recommendations involving flood warning-response actions.

1) In nearly every case, the recipient had implemented one or more of the team's recommendations. Three of the wastewater treatment plants in Pennsylvania had taken no action claiming that they had not yet received the team's report. The other 15 facilities had, at a minimum, taken steps to obtain existing flood warning information (i.e.; weather radio). Most had also taken the time to make or improve upon an emergency response plan. Two facilities, a wastewater treatment plant in Pennsylvania and a metal products fabricator in Baltimore, had developed emergency plans and provided them to the Baltimore District for review and comment. Based on their responses, about one half of the facilities were judged to have had a functional plan for evacuation of contents in effect at the time of the survey.

2) None of the 18 facilities surveyed undertook any major, capital intensive improvements to implement contingent dry floodproofing measures. However, last year one previously surveyed Baltimore industry requested additional assistance in selecting an engineering consultant to design a floodproofing plan. Only a few of the facilities surveyed have made any changes to existing equipment to facilitate its evacuation. These changes were mainly to install electrical quick disconnect plugs and connectors. Instead, facilities have elected to elevate new equipment installations to reduce its susceptibility to flooding.

Case History - Bloomsburg, Pennsylvania. In the latter part of 1980, surveys were conducted for five individual facilities in the Town of Bloomsburg, in Columbia County, Pennsylvania. These included four commercial or industrial businesses and the local wastewater treatment plant. After a flood event in December 1983, staff of the Susquehanna River Basin Commission (SRBC) conducted a follow-up survey to document the actions taken by these and other facilities throughout the community. The results of this survey were presented in a draft report (SRBC 1984). A summary of the report relating to implementation of the recommendations of the flood damage reduction survey team follows.

Flood forecasts issued by the NWS initially indicated a flood stage between 22 and 23 feet at Bloomsburg. This was later revised to 23 to 24 feet. Based on these predictions, all but one of the facilities surveyed by the team chose not to take any action. Even though their access routes are very low and known to be affected at the predicted stages, these facilities have floor elevations several feet higher than the predicted stages and elected not to do anything. One facility, which produces frozen foods, chose to take action based on the company officials' recognition that the predicted flood stage was within 1-foot of flooding access roads. Based on this perception of threat, the company spent 16 hours evacuating a portion of the 5 to 5-1/2 million pounds of frozen food in storage at the facility. This represents 26 tractor trailer loads of material evacuated.

Although it turned out to be unnecessary to evacuate the frozen food processing facility, documentation of this facilities' efforts shows that self-help flood damage reduction efforts can work.

Publications. As a direct result of the cooperative effort among federal, state, and regional agencies to perform flood damage reduction surveys, several publications have been prepared on self-help flood damage reduction, with emphasis on flood warning-response actions. Widespread use and dissemination of these publications has and will continue to foster awareness and application of these types of actions in reducing flood losses.

Prior to the inception of self-help damage reduction surveys, several federal and regional agencies recognized the need to document the efforts and results of self-help community and industrial flood warning-response actions in Lycoming County, Pennsylvania. The experience in Lycoming County provided a background from which self-help flood damage reduction surveys developed and drew ideas. The result was a multi-media project including a movie, a slide presentation, and a report which were prepared by the SEDA-

Council of Governments and the U.S. Water Resources Council.

1) Watch Along the Watershed (Filmspace 1981) is a 20-minute movie describing the County's self-help flood warning system and the successful flood preparedness actions taken by a local industry, Sprout-Waldron. The film was intended to serve as an introduction to such programs for community officials and industrial managers.

2) Early Flood Warning (Filmspace 1981) is a 12-minute, narrated slide show explaining the principles of self-help and cooperative action, development of a volunteer observer flood warning system, and the benefits of flood warning and preparedness.

3) Cooperative Flood Loss Reduction - A Technical Manual for Communities and Industry (Flood Loss Reduction Associates 1981) is intended for use by community officials, industrial plant managers, and others responsible for flood loss reduction. It describes the various approaches to reducing flood losses, with emphasis on self-help flood warning-response programs.

These products have been widely disseminated and used by federal, state, and regional agencies involved in flood loss reduction. They have appeared nationwide at seminars, workshops, meetings, and other situations where it has been necessary to illustrate the concepts and benefits of self-help flood loss reduction.

Another publication is entitled, General Recommendations and Procedures for Flood Damage Reduction at Wastewater Treatment Plants (Baltimore District 1983). This publication documents the results of an investigation of the flood problems of wastewater treatment plants which was conducted by the Baltimore District with the assistance of the interagency survey team. At the request of the Commonwealth of Pennsylvania, the team surveyed several different types of plants in different geographic regions. The study revealed several design related conditions contributing to the problem. Changes in design practices were recommended to reduce the susceptibility of new facilities. For existing plants, the team recommended a comprehensive set of flood damage reduction measures including the typical types of flood warning-response actions discussed earlier (i.e.; flood warning information, contingent floodproofing, and evacuation of contents). This publication has received nationwide publicity and is even known in several foreign countries. It has also served as a basis for training plant operators in Pennsylvania on the topic of emergency preparedness.

As result of team and related activities, the Pennsylvania Department of Community Affairs (PADCA) prepared a report entitled, Reducing Commercial and Industrial Flood Losses (PADCA 1984). This publication emphasizes the evacuation of contents as a practical approach to reducing commercial and industrial flood losses when other, more capital intensive approaches are not available. It is a document designed to guide the planning and development of an evacuation plan, beginning with information and advice on how to evaluate the flood hazard. The report discusses the role of flood warning, emphasizes the need for a written plan, and details methods and procedures for moving materials. It also covers post-flood recovery procedures, flood insurance, and floodproofing. This publication has been widely distributed among federal, state, regional, and local agencies and commercial and industrial interests.

Summary

This paper has examined the experience of the Baltimore District, Corps of Engineers, in conducting surveys to provide businesses and industries with advice and information on self-help flood damage reduction measures. In conjunction with other federal, state, and regional agencies, 31 surveys have been conducted of various types of commercial, industrial, and public utility facilities.

In every instance, some form of recommendations were made relating to flood warning-response actions. Every facility has been advised on how to obtain and use existing flood warning information as a basis for developing an effective response plan. To assist in the refinement of a plan, where data are available, relationships have been developed to correlate flood depth or elevation at a facility to the predicted flood stage at a nearby stream gage. To accommodate the need to make informed business investment decisions, these data have also been presented to show the probability of flooding for discrete periods of time ranging from one to thirty years. The flood warning-response actions typically recommended are contingent dry floodproofing and evacuation of contents. Either one or both actions may be recommended depending on the severity of the flood threat, available flood warning time, and structural integrity of buildings.

Several opportunities have come about to examine the effectiveness of this self-help program. These opportunities include follow-up surveys, a documented case history, and publications. Follow-up surveys of 18 facilities indicate that nearly all of them had taken steps to obtain flood warning information and that most had made an effort to make or improve upon an emergency response plan. About one half of the facilities were judged to have a functional plan and two facilities furnished copies of their plan to the District for review. None of the facilities surveyed had undertaken any significant contingent dry floodproofing measures, although one business had taken steps to hire an engineering consultant. A few facilities had made minor changes to improve the evacuation of equipment and several others had elevated new equipment installations.

The response actions taken by several facilities in the Town of Bloomsburg, Pennsylvania, in response to a recent flood were documented in a case history. This study showed that the facilities surveyed by the team are aware of their vulnerability and are prepared to take action, if warranted. One facility evacuated 26 truck loads of frozen flood, proving that they can evacuate contents to prevent damage.

As a result of the experiences of team member agencies, several multi-media publications have been prepared concerning self-help flood damage reduction as applicable to businesses, industries, and public wastewater treatment plants. These publications have received widespread distribution and recognition and have provided a basis for education in the form of training and seminars.

Conclusion

The emphasis of flood damage reduction surveys conducted by the Baltimore District, Corps of Engineers, and the interagency team is on self-help flood warning-response actions. Case studies demonstrate the success and benefits of such programs developed by flood prone businesses and industries. Although the benefits are clearly known, only a moderate degree of success has been achieved by the team in motivating businesses and industries to implement flood damage reduction plans. There are several factors contributing to the limited success realized.

Cost is probably the factor that has most strongly influenced what businesses and industries will do to reduce flood damages. For the most part, they will implement those actions which are not capital intensive. Such actions include arrangements to obtain flood warning information, development of a response plan, and minor modifications to improve the evacuability of contents. On new equipment, companies have also readily incurred the minor additional costs of elevated installations. None of the facilities surveyed have spent the large amounts of money needed to make major evacuation-related modifications or implement floodproofing.

Based on subjective observations, it appears that a company's response in implementing a flood damage reduction plan is also influenced by the presence or lack of support by a decision-making person within the organization. Those facilities which have made the most progress appear to have strong commitment and interest by high level management personnel. Those who have done little or nothing appear to have no support from management.

The final factor having significance in motivating businesses, industries, and communities to take action to reduce flood losses is the perception that a flood threat exists. Naturally, continuing and recent flood experience has a strong influence in the decision-making process. Theoretical flood frequency-elevation data, when presented in the proper context (i.e.; depth versus probability), may also be influential.

Solutions to the flood problems of individual businesses, industries, and public facilities will not come from capital intensive public works projects, but will be realized through self-help flood damage reduction programs. There is a strong commitment by the agencies supporting the flood damage reduction survey program to continue this activity. Although our success in motivating action has been limited, the results achieved to date are judged to have been worth the effort.

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FEASIBILITY INVESTIGATIONS OF LOCAL FLOOD WARNING-EMERGENCY PREPAREDNESS PLANS*

by Darryl W. Davis and Michael W. Burnham**

INTRODUCTION

Section 73 of PL 93-251 requires that nonstructural measures be among the alternatives considered in developing flood loss reduction plans. Local flood warning-emergency preparedness plans are nonstructural means for lessening the threat to social, economic, and physical elements of local communities during a flood event. The Corps of Engineers therefore considers the investigation of flood warning-emergency preparedness plans to be a normal component of performing comprehensive flood loss reduction feasibility studies. Participation by the Corps in the implementation of flood warning-emergency preparedness plans has typically been limited to acquisition of hardware and technical assistance in developing warning systems (U.S. Army Corps of Engineers 1983a).

The Corps also has other authorities that encourage participation in preparation of flood warning-emergency preparedness plans. Emergency Operations activities can, in specific instances, assist local agencies in preparing and implementing plans. Also, the Flood Plain Management Services program of the Corps can provide technical assistance to local agencies in preparing plans. Several notable assistance efforts have been participating in preparation of hurricane evacuation plans for the Southeast and Gulf Coast seaboards.

Local flood warning-emergency preparedness plans consist of hardware, technical activities, and formal and informal inter- and intra-organizational arrangements and commitments to performance in which the human element is a vital part. Federal, state, and local governmental agencies and private sector organizations that conduct programs and operations relevant to flood warning-emergency preparedness plans are numerous and diverse. The type and sophistication of the appropriate measures can vary significantly due to physical characteristics of the

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**Chief and Senior Engineer, respectively, Planning Division, The Hydrologic Engineering Center, Davis, CA.

stream system, the nature of the problem to the threatened area, resource availability, and institutional factors. The event response and management of a flood disaster, instead of the permanent (long-term) event control or damage potential modification, are unique characteristics of local flood warning-emergency response actions that differentiate them from other flood loss reduction measures. The feasibility study of local flood warning-emergency preparedness plans must therefore be tailored to account for these differences from other structural and nonstructural measures.

This paper defines the components of local flood warning-emergency preparedness plans, provides an overview of an investigation strategy, and describes methods for performing the technical elements of the study.

DESCRIPTION OF PLAN COMPONENTS

Local flood warning-emergency response plans are comprised of coordinated actions involving flood-threat recognition, warning dissemination, emergency response, post-flood recovery and re-occupation, and continuous plan management. Figure 1 shows the relationship of the plan components. The descriptions used herein are adopted from Owen 1976 and The Hydrologic Engineering Center 1979 and 1982a.

Flood Threat Recognition

Flood threat recognition consists of actions that enable early identification and subsequent monitoring of potential flood situations. These activities include weather forecasting, precipitation and/or streamflow measurements, runoff and stage forecasting, and transmission and subsequent processing of measured and forecasted data to monitor the flood threat. The methods vary significantly in type and sophistication depending upon the stream system characteristics and nature of the area at risk. Principal features often implemented are: computerized systems featuring automatic remote signaling capability between data recorders and forecasting or emergency operations centers, various water level sensing devices which alert monitoring officials, flood forecasting software, and networks of observers who record and forward precipitation and river stages to a central location for processing and interpretation.

Flood Warning Dissemination

Flood warning dissemination provides critical linkage between recognition of an impending flood and execution of emergency response actions. The process consists of three primary functions: provisions for decision on whether or not to issue a warning, formulation of the warning message and identification of the appropriate audience, and means (radio, television, sirens, bull horns, and door-to-door) of the

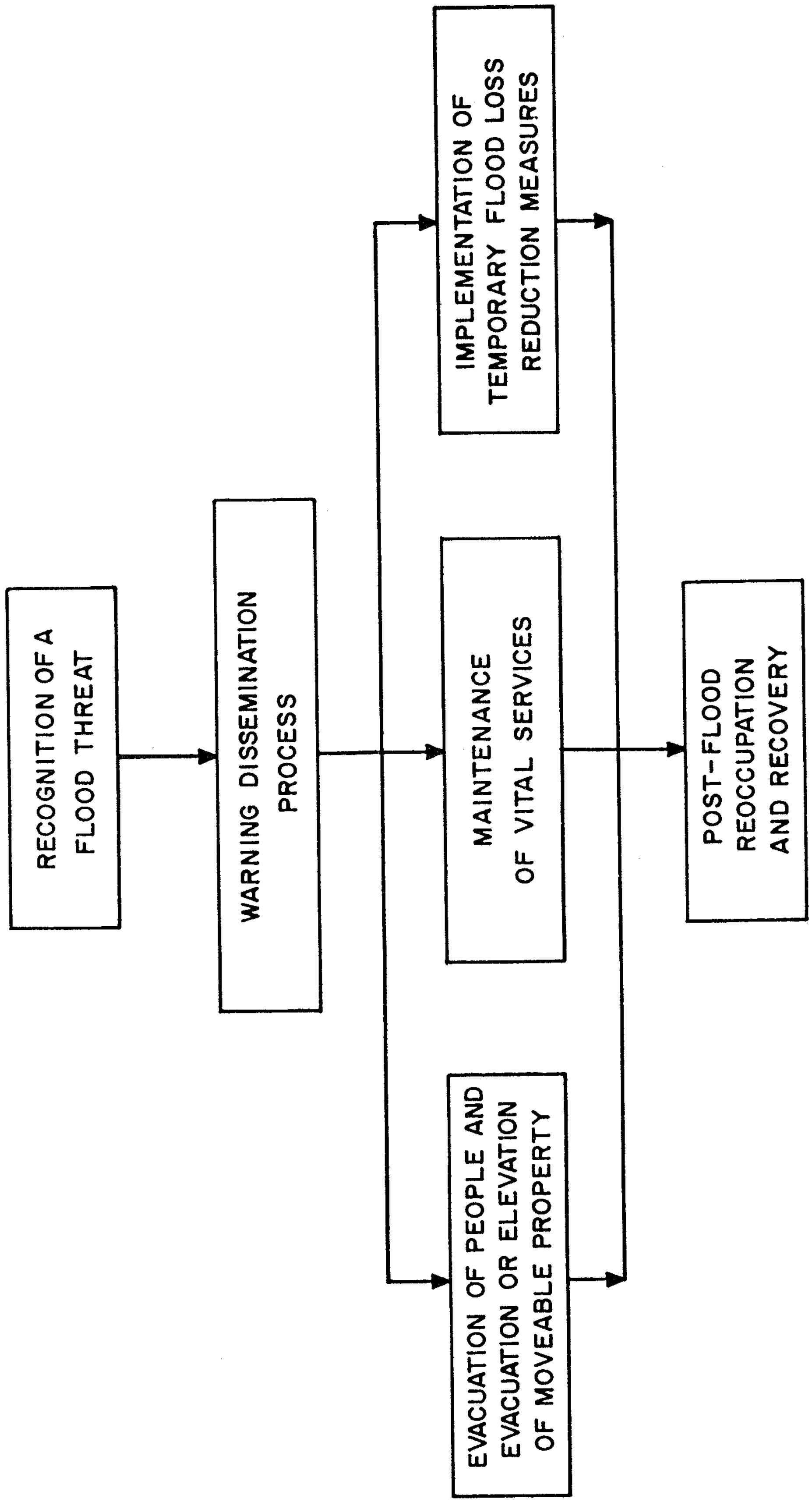

Figure 1 Flood Forecast, Warning, and Evacuation Strategy

distribution of the warning message. Individuals perceived to be under threat of the impending flood should personally receive the warning message from a recognized person in a position of authority (mayor, law-enforcement personnel, firemen, designated block party alert person, or similar). The message, orally presented or distributed as a written handout, should state the time before the flooding occurs, its expected severity, and describe appropriate response actions (such as evacuation routes, safe shelters, protective actions).

Emergency Response Actions

Emergency response activities occur immediately prior to and during a flood event. The actions are planned to reduce the threat to life and to lessen social and economic impacts of flooding. Objectives of emergency response actions vary according to the overall completeness of the preparedness plan and the nature of the flood threat and potential risk. Minimal plans (minimal hardware and plan details), are usually limited to measures and actions for the safety and general welfare of the public. Emergency response elements normally deal with: search and rescue of endangered people; temporary raising or removal of public and private property, flood fight efforts, and management of important services and facilities such as electric power, gas, water, sewage collection and disposal, fire suppression, law enforcement, and emergency medical service. The viability of the local flood warning-preparedness plan depends on how well the preparedness activities are conducted during a flood event.

Post-Flood Recovery and Re-occupation

Post-flood recovery and re-occupation consists of actions required to return to a near normal state as rapidly as possible after a flood has occurred. Specific measures and actions usually addressed include: return to normal operation of important services; means of preventing re-entry of now dangerous structures; and identification and provision of assistance to the general public and local governments.

Continued Plan Management

Successful implementation of a local flood warning-emergency preparedness plan during a flood requires a high level of communication, cooperation, and coordination among public and private organizations and the public. Interjurisdictional arrangements between municipal, county, and state governments are normally required if resulting preparedness plans are to be successful when implemented. These arrangements should be formalized and documented.

Without periodic application, the arrangements are likely to become obsolete or unworkable. Continued plan management provides for activities required to best assure the viability of the plan during periods between flood events. It involves:

updating portions of the plan subject to obsolescence (such as names and telephone numbers, assignments of responsibilities), means of maintenance and testing of equipment, and education of involved organizational personnel and the public as to the appropriate actions during a flood situation.

INVESTIGATION STRATEGY

Flood warning-emergency preparedness plans are one of a set of nonstructural flood damage mitigation measures considered in flood loss reduction feasibility studies. The Corps of Engineers planning policy governing flood loss reduction investigations is well established and documented in Principles and Guidelines (U.S. Army Corps of Engineers 1983b). Flood warning-emergency preparedness plans are to be considered in a manner similar to other measures. That is, flood hazard, flood damage, institutional, and other studies are conducted for existing and future with and without conditions. However, the relatively low cost of implementing the plans, normally $30,000-$70,000 for small communities up to $100,000-$300,000 for large areas, suggests that the feasibility study be conducted at low cost. The reconnaissance study level of detail seems appropriate in most instances. For larger, more complex basins, increased detail is warranted.

Alternative plans are to be formulated to address documented needs. They are evaluated in terms of their contribution to resolving the needs, and the best plan is selected and recommended for implementation. The plans are also evaluated and displayed in terms of their contributions to the national accounts of national economic development (NED), Environmental Quality (EQ), regional development, and social well-being.

The benefits of flood loss reduction plans are determined by comparison of the with and without project conditions. The without project condition is the project setting likely to occur as a result of existing improvements, laws and policies. The with project condition is the most likely project setting expected to exist in the future if the proposed project is undertaken.

A sequence of specific tasks is undertaken in a typical planning study. Investigating agencies may define and label the tasks slightly differently but they normally include problem identification, definition of existing and anticipated future conditions, formulation of alternative plans, evaluation of alternative plans, selection of the recommended plan and design of an implementation plan. The discussion that follows is meant to convey the notion of performing the analysis in a comprehensive systematic manner ... an organized way of thinking and conducting the study. It is not intended that a highly detailed and involved process be undertaken. The manner of undertaking the study should of course be scaled to the scope of the problem and likely solutions.

Problem Definition

The nature of the existing flood hazard must be carefully and completely defined. Is the flooding potential swift and potentially catastrophic; or slow and perhaps mostly a nuisance? Where is the flooding most severe and how predictable is it? What needs to be known to improve the situation? These are the questions for which answers are needed to identify the flood problem.

Conditions Definition

In most instances, some form of emergency action presently takes place during a flood event. It is useful to document the existing arrangements, procedures, and capabilities for flood threat recognition; flood warning dissemination; emergency response actions; post flood recovery and re-occupation; and continued plan management. Complete documentation of the present and likely future conditions provides a firm basis for formulation of plans of improvement.

Plans Formulation

Two or more plans are to be formulated that address the problem as identified considering the present and expected future conditions without the plan. It is normally useful to formulate distinctly different alternative plans in order to identify the range of possible improvements. Plans of improvement are most likely to be enhancements to existing arrangements and planned action. Each element of the flood warning-emergency preparedness is to be addressed to ensure formulation of responsive, complete, and comprehensive plans.

Plans Evaluation

The alternative plans formulated are to be evaluated from several perspectives. Issues of legal and institutional feasibility are important as well as costs, benefits, and implementation practicality. It is important to determine whether the formulated plans will perform as intended, and define the costs and benefits of each. Differences between plans are important since they will provide the basis for plan selection. The plan formulation/evaluation process is not linear but instead is iterative. Insights obtained during the evaluation phase should be used in refining the formulated plans.

Plan Selection and Implementation Strategy

The recommended plan must normally be the one with the greatest net contribution to the NED account. Exceptions are possible if it is clearly demonstrated why another plan is more appropriate. In any event, for the plan to be recommended for federal action, the contribution to the NED account must be positive.

An implementation plan is to be designed that specifies the actions by the responsible authorities to bring the plan to fruition. Cost sharing agreements, institutional cooperation requirements, and similar items need development to assure decision makers that a complete plan is ready for implementation.

TECHNICAL ANALYSIS

The four technical analyses discussed were selected to emphasize important aspects of studying flood warning-emergency preparedness systems. They are flood hazard analysis, flood damage evaluations, institutional analysis of existing arrangements, and flood scenarios of observed and potential flood episodes for existing conditions.

Flood Hazard Analysis

Flood hazard analyses are performed to provide information on the flood characteristics of an area. The flood hazard data provides information on the potential for the loss of life, impacts to important community functions, and is required for flood damage evaluations. The analyses include hydrologic and hydraulic studies of existing and future with and without conditions.

Flood hazard analysis provides basic information for defining the existing flood hazard and developing key elements of local flood warning-emergency preparedness plan enhancements. Hydrologic studies are normally performed on observed records where available, supplemented by rainfall-runoff analysis of observed and hypothetical frequency events. The analyses produce flood hydrographs at specified control points throughout the study area. Hydraulic studies are conducted by analyzing a series of water surface profiles throughout the study area to develop inundated area maps and stage hydrographs. Many Corps technical manuals and computer programs are available to assist in performing the hydraulics and hydrology studies. The type of flood hazard information that can be developed is listed below.

(1) Flood inundation boundary maps for various flood stages and discharges. These maps may be used to define the number and type of threatened structures, roads, and other vital services. They may also be used to define the priority order of the warning and emergency response plans and actions, and to assist in emergency operations during a flood event.

(2) Warning times for various levels of flooding.

(3) Estimations of depth and velocity relationships for various levels of flooding. These relationships along with corresponding warning times may be used to identify areas of significant risks to the inhabitants.

(4) Evaluations of the effectiveness and reliability of flood threat recognition systems including those related to flood forecasting.

(5) Discharge-frequency relationships at control points that are required for plan evaluation.

(6) Discharge-elevation relationships at control points that are required for plan evaluation.

Similar hydrologic and hydraulic studies are required for future without conditions and for the plan enhancements analyzed if these conditions effectively alter the hydrology and hydraulics of the study area. The warning time and associated reliability may be significantly enhanced via improvements to the flood threat recognition process, such as installation of a more automated flood forecasting system, and from better warning dissemination plans.

Flood Damage Evaluation

Flood inundation damage analyses are performed to identify potential damage locations, the type of damage, and the damage reduction associated with implementing temporary flood loss reduction actions such as flood fighting, installation of temporary barriers, and removal or raising of contents.

Flood damage evaluations of existing conditions are performed by development of elevation-damage relationships at damage reach index locations where hydrologic (discharge-frequency relationships) and hydraulic (discharge-elevation relationships) data have been developed. The elevation-damage relationships are generated by aggregating by damage categories the respective functions of individual structures of a damage reach to a selected reach index location. Damage categories are specified to sufficient detail to enable appropriate evaluations of flood loss reduction measures. The damage relationships may be calibrated to observed flood damage survey and other available data (Hydrologic Engineering Center 1982b).

The existing without condition expected annual damage is calculated by damage category and reach by integrating the damage-frequency relationships obtained by combining the hydrologic, hydraulic, and damage data. Future without condition expected annual damage calculations are performed for future time periods throughout the project life as projected changes in conditions warrant. The without conditions equivalent annual damage may then be calculated by discounting the time stream of expected annual damage to the beginning period of the analysis and amortizing over the planning horizon (Hydrologic Engineering Center 1984).

The with condition damage analysis evaluates the residual damage expected to occur if enhancements to existing local flood warning-emergency preparedness plans are implemented. Actions that reduce the flood damage are: enhanced flood threat recognition, including forecasting, and warning dissemination processes. These can result in more reliable and greater warning times and encourage subsequent enhanced implementation of temporary flood loss reduction measures as a result of better warning, or perhaps development of better planned implementation actions. Temporary flood loss reduction measures include perimeter barriers around individual or groups of structures, and raising or removal of contents.

The calculation of the with plan conditions are performed in a similar manner as the without conditions. The elevation-damage relationships of the individual structures are modified to reflect the implementation of the measures. Figure 2 shows an example of these modified relationships. The with plan expected

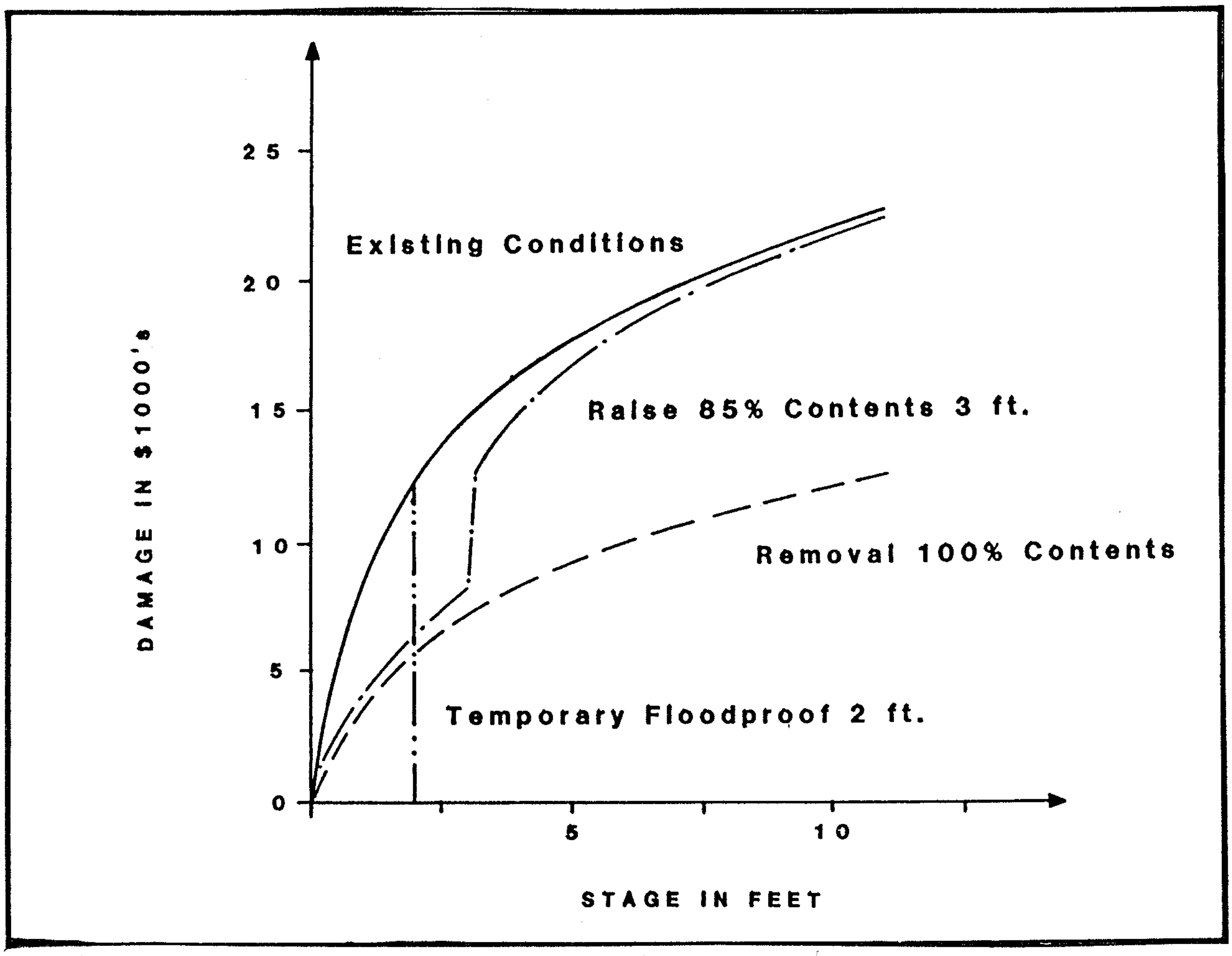

Figure 2 Stage Damage Relationships

annual damage and equivalent annual damage calculations are performed as described above. The difference between the with and without conditions damage values represent the inundation reduction benefit for the plan enhancements. A more detailed description of benefits is presented later.

Institutional Analysis

Institutional analysis is the study of formal and informal organizational arrangements for communication, coordination, and conduct of operations required to implement a local flood warning-emergency preparedness plan. It is a principal aspect of the formulation process due to the required interaction of an often large number of organizations needed to successfully implement a successful flood warning-preparedness plan. Specifically, the institution analysis should define the information collection, processing, and dissemination processes of each plan component. The organizational authorities, responsibilities, and general capabilities to implement potential plan enhancements must also be determined. Finally, the cost sharing arrangements to plan, design, and implement the plan enhancements must be negotiated and ultimately defined.

The analysis of the present institutional arrangements may be performed by review of existing documented plan arrangements, review of past flood records, and interviews of responsible officials. Interviews should involve local, state, and federal agency personnel participating in the flood warning-emergency preparedness plans, and others including local residents that have experienced floods. Particular attention should be given to those involved in early recognition and forecasting of floods, warning dissemination, emergency operations center, search and rescue, and management of vital services. Those interviewed should be of responsible positions and actively involved in the flood emergencies. Questions must be phrased to obtain information concerning present arrangements, existing and potential problems, and possible solutions. The questions should pertain to observed events and the consequences of perhaps as yet not experienced large events such as the .01 percent chance event and the Standard Project flood.

The focus of the institutional analysis should begin with the flood operations center which normally is part of the county's emergency operations center for natural and other disasters. Many of the functions and general responsibilities are coordinated by the same organizations for any disaster. The number of coordinators participating in the emergency operations should be minimized to provide issuance of consistent and precise information. The responsibilities of the coordinators and director of the emergency operations center should be well defined in the disaster plans. Analysis should review previous operations and propose enhancements in the coordination and responsibilities of the participants. An example of the coordinators and their functions in an emergency operations center is shown in Figure 3.

Special effort is required to identify informal arrangements since they can reduce the reliability of the plan and significantly hinder anticipated actions during a flood episode. Informal arrangements should be minimized by formalizing to the extent possible, those arrangements that contribute to the planned actions and eliminating those arrangements that do not contribute in a positive manner. Identification of informal arrangements is normally accomplished via the interview process.

Schematics, such as shown on Figure 4a for an existing warning dissemination process, which show the responsible organizations and lines of formal and informal communications can assist in defining the existing arrangements of the plan component. It also provides a means to obtain general agreement among the participating agencies as to the existing functional arrangements and often clearly indicates needed enhancements. A modified schematic (Figure 4b) which shows the enhanced procedures may subsequently be developed as part of the agreed upon arrangements. Similar schematics should be developed for the flood threat recognition (forecast), warning dissemination, emergency response, and other activities associated with existing and enhanced local flood warning-emergency preparedness plans.

Flood Scenarios

Social scientists performing natural and man related disaster assessments have utilized flood scenarios as a means to describe disaster situations and the social impacts related to the disaster. Scenarios provide descriptive reinactments of past events or may hypothesize situations in order to provide more explicit descriptions of possible catastrophic consequences and actions associated with potential events. The narratives enable sequential descriptions of integrated disaster reactions and often bring forth a realism and understanding not possible in the technical analysis format.

Flood scenarios are at times useful methods for highlighting the value of enhancements to local flood warning-emergency preparedness plans due to the event nature of implementing a sequential set of flood threat recognition, warning dissemination, and emergency response actions. The scenarios can tie together the sequence of institutional operations, flood hazard data and impacts, and flood damage consequences. In addition, risk to life and numerous other social impacts can be described in a realism not possible using technical reporting techniques. The flood scenarios should be developed after the flood hazard analysis, flood damage evaluations, and the institutional analyses are completed.

If possible, a scenario should be derived from a recent observed event. The material to develop the scenario may come from reports and notes of the operations center, the

DIRECTOR
Maricopa County Civil Defense

LAW ENFORCEMENT COORDINATOR
(Sheriff's Department)

FUNCTIONS:

1. Incoming information from law enforcement agencies
2. Warning dissemination
3. Coordination of law enforcement activities
   - A. Warning
   - B. Rescue
   - C. Traffic control
   - D. Surveillance

PUBLIC ASSISTANCE COORDINATOR
(County Safety Department)

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of volunteer activities
   - A. Shelter
   - B. Feeding
   - C. Floodfighting
   - D. Post-flood recovery

PUBLIC WORKS COORDINATOR

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of public works and utilities
   - A. Monitoring
   - B. Curtailment of service
   - C. Restoration of service

FIRE SERVICES COORDINATOR

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of fire department activities
   - A. Warning (back-up)
   - B. Emergency medical

MEDICAL SERVICES COORDINATOR
(County Health Department)

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of medical services
   - A. Air evacuation
   - B. Distribution of supplies
   - C. Distribution of injured
4. Post-flood health measures

EMERGENCY OPERATIONS COORDINATOR
(Flood Control District)

FUNCTIONS:

1. Warning dissemination
2. Coordination with federal agencies
3. Coordination with state agencies
4. Floodfighting
5. Property damage reduction measures

MEDIA SPOKESMAN
(MCCD Staff)

FUNCTIONS:

1. Press briefing
2. Rumor control

Figure 3 ENHANCED EMERGENCY OPERATIONS CENTER ORGANIZATION

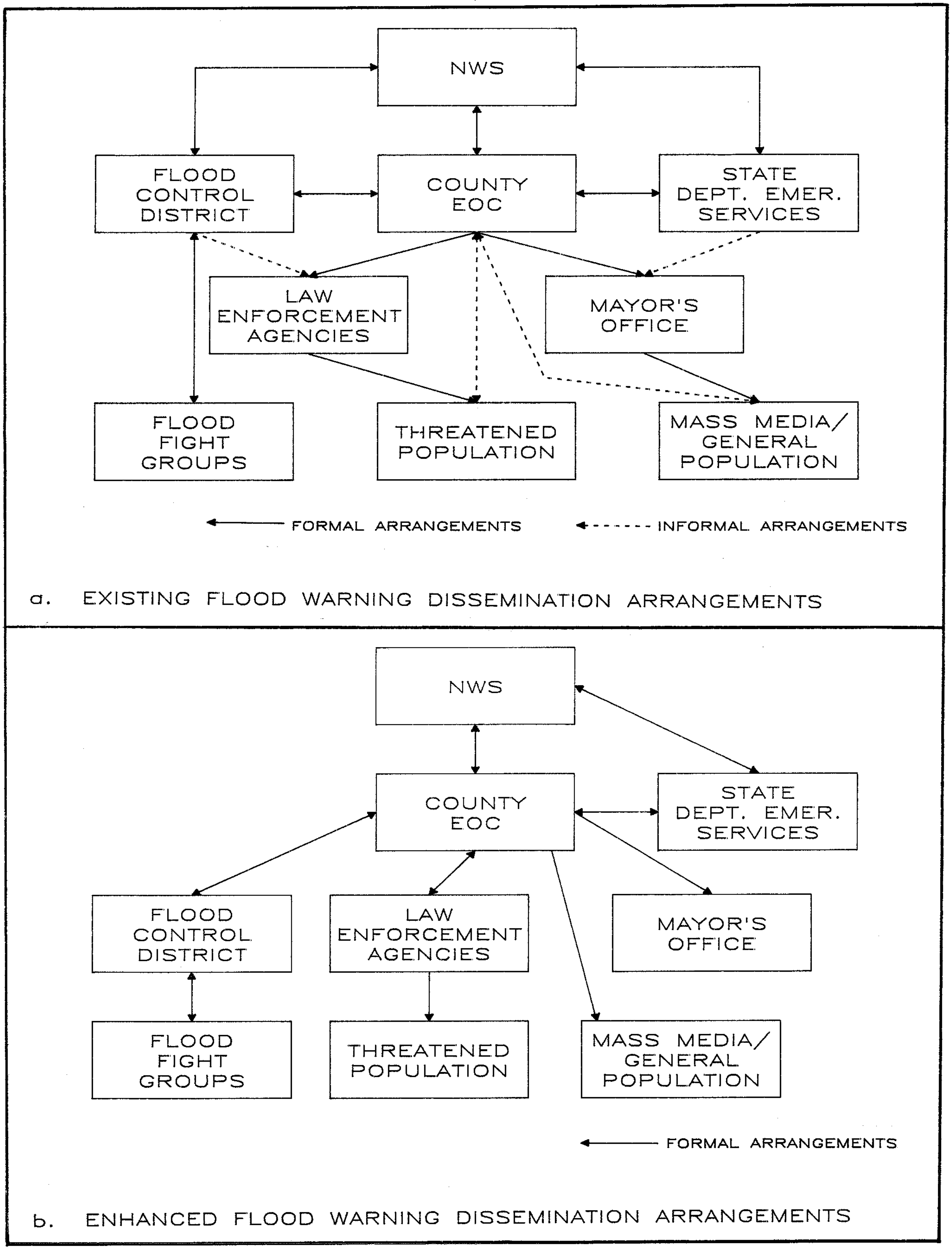

FIGURE 4 Flood Warning Dissemination Arrangements

institutional analyses, flood hazard information, and flood damage data including post flood damage surveys for recent flood events. A brief excerpt of a flood scenario for an observed event is presented below (The Hydrologic Engineering Center 1982).

> By noon on the second day of February, the discharge through the metropolitan area was estimated to be 160,000 cfs and was predicted to increased to 180,000 cfs by 5:00 p.m. Over 2000 residents had been evacuated on recommendations of the emergency operations center. Assistance was being provided by the National Guard called to duty by the Governor. Police were continuously issuing additional warning to the incorporated areas, and the Sheriff's department issuing warnings to outlying areas. Three mass care centers were in operation at the local schools.

The scenario derived from an observed event can be used to develop a scenario of a large perhaps as yet not experienced hypothetical flood (such as a Standard Project Flood) for existing conditions. Changes since the observed event to physical conditions, institutional arrangements, and the local flood warning-emergency preparedness plan event should be incorporated into the scenario. The scenario of the hypothetical event should include situations and consequences that are possible, even though their simultaneous occurrence during a given event may be highly unlikely. The intent is to identify potential problems and to incorporate formal arrangements and actions into the local flood warning-emergency response plan to negate or minimize their impact.

The scenario for the hypothetical event may be modified after enhancements to the local flood warning-emergency preparedness plan are identified to reflect these changes. This scenario could then help communicate the contribution of enhancements to the local flood warning-emergency preparedness plan and to describe in an understandable way the residual consequences that may still occur during a large flood even with the plan in place.

BENEFIT-COST ANALYSES

The analysis by the Corps of Engineers and other Federal agencies of enhancements to local flood warning-emergency response plans requires that benefit-cost evaluations be performed and the contribution to the National Economic Development account be displayed as an output of the study. The objective of the benefit-cost analysis is to identify, array, and to estimate the cost of actions needed to bring an alternative into operational service and to maintain its viability; and to identify, array and value the output (benefit) of the alternative in commensurate units so that the justification of the investment may be determined. The components of local flood warning-emergency plans are varied and difficult to array and evaluate under the conventional cost and benefit methods. Work is needed to provide a more firm basis for performing the analysis and presenting the results. The examples presented are taken from The Hydrologic Engineering Center's report Flood Preparedness Planning: Metropolitan Phoenix Area (1982a).

Costs

Costs required to implement the enhancements consist of first costs of investigating and implementing the plan enhancements, annual costs of maintaining plan components in a state-of-readiness, and the periodic costs associated with implementing specific actions during flood events. Table 1 summarizes the general cost items associated with implementing a local flood warning-emergency preparedness plan.

TABLE 1

Example Cost Items
Flood Warning - Emergency Preparedness Plan

First Costs

Development of plans
Outfitting/equipping of administrative facilities
Purchase and installation of equipment and hardware
Development/printing brochures, instructions
Stockpiling equipment and materials

Annual Periodic Costs

Updating flood recognition methods, and formal warning, response, recovery, and continuous management plans
Updating/printing brochures, instructions, etc.
Operation drills
Supplement/replace stockpiled materials
Equipment/hardware operations, maintenance and replacement

Event Costs

Personnel overtime and emergency hiring
Equipment purchase and rental
Transportation/storage of personnel property
Materials/supplies consumed
Mass care operations

It is difficult to distinguish between local flood warning-response plan cost items that fall under the preview of existing agency operations and those not accounted for under existing conditions. The most credible approach is to assign most administrative costs to existing on-going programs and to separate out those items specifically attributed to the proposed enhancements to the existing plans. The cost items listed in Table 1 may be adjusted and tailored to the specific situations and conditions being studied. An example of a summary analysis of first and annual costs associated with enhancements to a local flood warning-emergency preparedness plan is shown on Table 2.

TABLE 2

Example Cost Estimation Summary

First Cost

Item	Cost Range ($1000)		
Preparation of Plan	$ 75	-	$100
Office/Administration Outfitting[1]	0	-	0
Equipment/Hardware	60	-	80
Information/Brochures	75	-	125
Equipment/Materials (Agency Use)	75	-	100
Equipment/Materials (Temporary Flood Loss Reduction Requirements)	75	-	75
Sub Totals	$360	-	$480
Amortized (50 yr. @ 7-3/4%)	$ 28	-	$ 38

Annual Cost

Item	Cost Range ($1000)		
Equipment/Hardware OM&R	$ 10	-	$ 20
Storage/Rent Equipment and Space	5	-	10
Public Information/Brochures, Drills	15	-	25
Flood Loss Reduction Materials	20	-	20
Sub Totals	$ 50	-	$ 75
Total Annual Cost Range	$ 78	-	$113

[1] Assumed part of normal agency costs

Costs incurred during flood events occur in a sporadic manner and are related to the magnitude of the flood event. To place them on a comparable basis, they must be converted to expected annual values, similar to flood damage. The logical way to accomplish this is to develop event costs by exceedance frequency of flood events, form a damage probability function, and compute the expected value just as is done with flood damage.

Re-evaluating the expected annual event costs for the several alternatives under study permits a sound basis for comparison.

Benefits

The benefits from enhancements to local flood warning-emergency preparedness plans are reduction to loss of life, and the reduction of the negative impacts of flood disasters on society in terms of reduced social disruption, business losses, and damage to private and public building and facilities. Table 3 summarizes general benefit categories of enhancements to local flood warning-emergency preparedness plans.

TABLE 3

General Benefit Categories

Category	Contributing Action
Reduced threat to life	Barricades, evacuations, rescues, public awareness
Reduced social disruption	Traffic management, emergency services, public awareness
Reduced health hazards	Evacuations, public information, emergency services
Reduced disruption of services	Utility shutoffs, emergency supplies, inspection, public information
Reduced cleanup costs	Flood fighting, self-help loss reduction, efficient resource use
Reduction in inundation damage	Flood fighting, temporary measures, technical assistance

The contribution to increased effectiveness and efficiency of emergency response actions by numerical values is difficult using present benefit analysis procedures. Debates as to valuing the saving of lives and reducing the threats to lives and property have occurred for many years and are continuing. The growing activities in the United States in the implementation of local flood warning-emergency preparedness plans provides evidence that society generally places sufficient value on these activities to support use of public finances and other resources to increase their responsiveness and utility.

The implementation of temporary flood loss reduction actions lends itself to conventional flood inundation reduction benefit analysis techniques. These benefits are attributed to enhanced flood threat recognition methods that result in greater and more reliable warning times, more efficient warning disseminations, and better emergency response actions.

An example of damage reduction (inundation reduction benefits) is shown on Table 4. The table lists the annual flood damage for a community for existing (without) conditions as determined from flood damage evaluations. The damage that would be reduced from implementing temporary flood loss reduction actions, assuming 100 percent effectiveness, may also be determined from flood damage studies. These measures may include implementation of perimeter barriers one foot high, removal of contents to a safe location, and raising of 85 percent of the contents three feet high. Finally, the annual damage reduced is adjusted to account for the proportion of the residents in the threatened area attempting the measures and of those attempting, the proportion that were successful.

TABLE 4

Damage Reduction Analysis Example

Measure	Annual Damage ($1000)	Annual Damage Reduced ($1000)	Adjusted[1] Reduction ($1000)
Existing (Without) Conditions	$2,450	$ 0	$ 0
1 Foot Barrier	2,140	310	47
40% Content Removal	1,680	770	77
85% Content Raise	2,070	380	92
		Total	$ 216

[1] Perimeter Barrier - 30% attempted, 50% effective
Content Removal - 20% removed 50% of contents
Contents raised - 40% raised 85% of contents 3 feet

EPILOGUE

Plan Design

Implementation of a successful flood warning-emergency preparedness plan requires design of formal arrangements for communication and conduct of operations, and the capability to adapt these arrangements to meet possible flooding conditions that would have significant negative effects on the area. The design must also be flexible to assure high adaptability to unforeseen flood situations that often occur during flood events. The plans must be periodically updated to reflect changed conditions to the flood event, impact area, and to the formal arrangement for conducting the flood warning-emergency preparedness plan. An understanding of the purpose and interface of the components that constitute a flood warning-emergency preparedness plan is paramount to implementing viable actions during a flood episode.

Cost Sharing

The specification and itemization of the cost for enhancements to local flood warning-emergency preparedness plans coupled with the institutional analyses lends itself to defining cost sharing arrangements for the plan enhancements. In general, many of the first costs may be borne by federal agencies if those agencies have performed or participated in the study. However, development of formal plans, written documents of procedural actions, and administrative arrangements must out of necessity be developed by local agencies. These costs may possibly be credited to the local cost contribution for the study.

Annual costs for administration, maintenance and operations, and for the conduct of periodic drills are normally costs to the local agencies. The costs incurred during flood events are generally distributed among numerous federal, state, and local agencies and the private sector. These costs would include those specified on Table 1.

Perspective and Issues

Local flood warning-emergency preparedness plans are comprised of flood threat recognition, warning dissemination, emergency response, post flood recovery, and continuing education plans and actions. Local flood warning-emergency preparedness plans may be implemented as either stand-alone measures or as enhancements to other existing or proposed flood loss reduction measures and actions.

The major emphasis by federal agencies to date of implementation of local flood warning-emergency preparedness plans has been the installation of flood forecasting hardware, equipment, and enhanced operation procedures of existing federal projects. While these activities are performed to yield earlier recognition of flood threats and more reliable forecasts, little consideration is often given to the value or compatibility of the investment and enhancements to the other components and the overall plan of the impacted area. The benefits and subsequent feasibility of any measure is determined from its incrementally enhanced response actions that reduce the potential risk to life, reduce flood damage, and assist in better management of social disruption.

The components of local flood warning-emergency preparedness plans have been defined and a strategy for determining the feasibility of implementing plan enhancements presented herein. Technical studies that are important for formulating enhancements to components of local flood warning-emergency preparedness plans have also been described and a proposed simple quantitative method of measuring the benefits and costs of plan enhancements presented. While the discussion is by design consistent with Federal agency guidelines for evaluations of flood loss reduction measures, it is also recognized that they must be tailored to the specific study conditions and special nature of flood warning -emergency preparedness plans. The intent is to demonstrate that formulation and evaluation of comprehensive plans is appropriate and that it should be a normal part of the process. However, due to the relatively small costs of implementing these plans and actions it is also recognized that the appropriate level of detail of the feasibility study should be scaled to the scope of its problem and likely solution. The reconnaissance study level is probably appropriate in most instances.

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LOCAL FLOOD WARNING & RESPONSE SYSTEM WORK GROUP
(LFW&RS WORK GROUP)

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INTRODUCTION. Many federal agencies have taken actions in using LFW&RS over the last several years. This effort has created a need for cooperation and coordination between the various federal agencies concerned with the action. In response to this need a LFW&RS work group was established as a way to further communications among participates. The work group has meet periodically and is a gathering of representatives from federal agencies plus other invited non-federal individuals. The get togethers serve common agency interests and has provided a forum for discussion, shared work efforts and agreements. The work group has caused a synergism of shared effort that produced a well received publication and other initiatives not achievable within a single agency or individual. At present the group is actively engaged in " getting the word out " to interested individuals or communities. So far I have given you a brief overview of why the group was formed, who the members are, what it has accomplished, and where it is going. In my remaining time I will provide a broader depth of why, who, what, and where but organize the presentation into three topic areas of background, history and present direction of the LFW&RS work group.

BACKGROUND. The Hydrology Subcommittee sponsors the LFW&RS work group. At one time the Water Resources Council sponsored the Hydrology Subcommittee. But the council is no longer, so the present sponsor for the Hydrology Subcommittee is the U.S. Geological Survey, Office of Water Data Coordination. The mission is still the same, the membership the same, etc., only the formal sponsorship changed.

The Hydrology Subcommittee has six work groups of which LFW&RS work group is one. The other five are Radio Frequency, Small Urban Watersheds, Bulletin 17, STIWG, and Network Analysis. This fall (1986) another group finished their work, distributed a publication of their efforts, and disbanded. This group was called PMF Risk Assessment Work Group and their publication was entitled FEASIBILITY OF ASSIGNING A PROBABILITY TO THE PROBABLE MAXIMUM FLOOD and dated June 1986.

The LFW&RS work group is composed of nine federal agencies plus two associate groups that receive the minutes of the group and provide input from time to time. The membership role has always been flexible and has included active involvement of state agencies in past writing efforts. The only real criteria has been consensus of the group and interest of the other group or agency. Formally any member of the Hydrology Subcommittee can be a member of the LFW&RS work group and most are. At present the formal group is composed of the following:

AGENCY	INDIVIDUAL	PHONE
National Weather Surface	Curt Barrett	301/427-7659
Tennessee Valley Authority	Don Newton	615/632-6222
Soil Conservation Service	Joe Hugh &	202/447-4909
	Jim Stingel	215/499-3940
Corps of Engineers	Lew Smith &	202/272-8506
	Jerry Peterson	202/272-0169
Federal Emergency Management Agency	Bill Judkins	202/646-2770
U.S. Geological Survey	Bruce Parks	703/648-5020
Bureau of Reclamation	Wayne Graham	303/236-3785
National Park Service	Charles Karpowicz	202/343-1345
Housing and Urban Development	Truman Goins	202/755-7894

The associate members are: California ALERT Users Group and the Association of State Flood Plain Managers.

HISTORY. The Hydrology Subcommittee recognized in 1982 a need for a " how to " manual on LFW&RS. The Subcommittee formalized the need in 1983 and created the LFW&RS work group to accomplished this mission with agency members. The group got started in the Spring of '83; elected Curt Barrett of National Weather Service in Silver Springs, MD as the first chairman of the group; invited representatives of the State of Maryland and the Commonwealth of Pennsylvania to participate as representatives of the Association of State Flood Plain Managers; defined the writing mission given use with more specifics; generated a draft outline of the " how to " manual; assigned writing tasks among the various members in the work group; set dates to accomplish tasks; and met every two or three months to edit each others writing efforts. Still the task took two years and would have taken much longer if not for Curt's prodding, pushing, guiding and most important doing. The completed 104 page manual was entitled GUIDELINES ON COMMUNITY LOCAL FLOOD WARNING AND RESPONSE SYSTEMS; went out for agency review in the spring of '85; 10,000 copies were printed in August '85; and the various federal agencies started distributing their copies soon after this. The Corps of Engineers distributed 400 copies amongst all the districts, divisions, and labs of the Corps. Other federal agencies had similar distributions. The National Weather Service distributed their agency copies so that all counties in the Untied States could receive one (this required most of the 10,000 copies printed.) The total effect was a very wide distribution within the federal agencies and at the local levels.

The manual was well received with recognition in the technical literature. This brought on subsequent requests for additional copies and soon the extra copies saved back were exhausted. Extra copies were printed when requests came and the manual was finally given to the National Technical Information Service (NTIS) in Springfield,VA for further requests. The NTIS stock number is PB86109717 and a copy costs about 20 dollars. Having completed our mission of publishing a " how to " manual on LFW&RS, the work group disbanded after recommending to the Hydrology Subcommittee that a permanent work group be formed with the following missions :

- exchange of information among the various users of LFW&RS
- development of and obtaining acceptance of any needed national level guidance/standards concerning LFW&RS
- help get the word out on LFW&RS merits and uses

In response, the Hydrology Subcommittee established a permanent LFW&RS work group with the above missions in the fall of '85. With these missions as a mandate, the LFW&RS work group sponsored two sessions concerning LFW&RS at the June 1986 meeting of the Association of State Flood Plain Managers. At the same meeting the National Weather Service acting for the work group helped finalize voluntary standards developed concerning communication formats used in the ALERT hardware devices.

Before leaving the discussion of the history the leadership of the group needs listing:

INDIVIDUAL	AGENCY	FUNCTION	TENURE
Curt Barrett	National Weather Service	Chairman	1983-5
Bill Judkins	Federal Emergency Management Agency	Chairman	1985-6
Lew Smith	Corps of Engineers	Chairman	1986-7
Bruce Parks	U.S. Geological Survey	Recording Secretary	1985-7

PRESENT DIRECTION. At present the work group has seven separate activities going at once. The responsibility is dispersed with members providing either leadership or support to the separate efforts. The following list contains a summary of these activities:

ACTIVITY	LEAD ROLE
Sponsorship of technical session at Engineering Hydrology Symposium in the ASCE Hydraulics Specialty Conference in August 1987	Lew Smith
Participation in June 1987 Conference in rememberance of the Rapid City,SD disaster 15 years ago	Bruce Parks
Sponsorship or participation in future conferences	Wayne Graham
Communications standards proposed by National Weather Service adopted by all users of ALERT system	Curt Barrett
Developing an information leaflet concerning the merits and uses of LFW&RS for use by all agencies	Jim Stingel
Distribution of Corps technical guidance from R&D program at Hydrologic Engineering Center	Lew Smith
Upstream dam emergency action plan tied to response plan of the LFW&RS of the locals	Don Newton

Many of these activities expire within the fiscal year. New ones will then be added, probably in the last quarter of this fiscal year. All of the items will fulfill the mission or the charter given the group. Much effort goes into defining these activities for sponsorship by the group. The mixture, flavor, and energy directed at the chosen activities will be a function of interests and energy of chairman and of agency resources directed at the activities. In a similar way, the guidance/standards will require consensus of all to become an interagency position and will reflect the initiative and energy of individuals within the group. The activities will also reflect, I believe, the agency interest as follows:

AGENCY	INTEREST
National Weather Service	Expanding the useable data network for real time runoff forecasts
U.S. Geological Survey	Water data information use
Bureau of Reclamation	LFW&RS use with dam safety
Tennessee Valley Authority	General use of LFW&RS technique in agency missions

(cont'd) <u>AGENCY</u>	<u>INTEREST</u>
Soil Conservation Service	General use of LFW&RS technique in agency missions
Corps of Engineers	General use of LFW&RS techniques in agency mission

Finally, I believe the collective efforts of many agencies (federal, state, and local) combined with hardware innovations from the vendors and sprinkled with a lot of drive and energy of individuals can make Local Flood Warning and Response Systems work for the safety of local communities and for the good of our country.

CORPS' ROLE PANEL PARTICIPANTS

PANEL DISCUSSION TOPIC: Role of Corps of Engineers in the Planning, Design, and Implementation of Local Flood Warning - Response Systems

MODERATOR: James R. Hanchey, Institute of Water Resources, Corps of Engineers

Jerome Peterson, Office of Chief of Engineers, Corps of Engineers

Curtis B. Barrett, National Weather Service

H. James Owen, Flood Loss Reduction ASsociates

Robert A. Pietrowsky, New York District, Corps of Engineers

SUMMARY: CORPS' ROLE PANEL DISCUSSION

The Corps of Engineers performs analysis and implements elements of flood warning - response systems under several types of studies and programs. They include flood loss reduction studies, technical assistance as part of floodplain management services, real-time water control, dam emergency evacuation planning, and emergency operations programs. These activities demonstrate the capabilities and responsibilities of the Corps in performing evaluations and implementation of local flood warning - emergency preparedness plans. There was general agreement that the Corps should continue to study and implement local flood warning - response systems within the framework of these programs.

The panel discussed in detail the role of the Corps to plan and implement local flood warning - emergency response plans for flood loss reduction studies. They may be studied and installed as interim measures until other other measures are installed, as integral components to other measures, and as stand-alone measures if other actions are not feasible. If other measures are found infeasible, it seems likely in urban areas and flash flood situations (with a potential for loss of life) that some elements of local flood warning - emergency preparedness plans will be justified.

The Corps' investigations of local flood warning - response systems should be performed in a comprehensive manner, especially in regards to the viability of the response plans and actions. The panel and seminar participants agreed that the details of specific response plans are generally the responsibility of the local agencies.

The Corps Flood Plain Management Services program has a potentially viable role in providing technical services to communities in the planning and implementation of local flood warning - response systems. The services provided may include providing technical information to: communities, self-help assistance to specific businesses, agencies, and individuals; and the actual conduct of the studies.

RESEARCH NEEDS PANEL PARTICIPANTS

DISCUSSION TOPIC: Definition of Needed Research for the Planning, Design, and Implementation of Local Flood Warning - Response Systems.

MODERATOR: Arlen D. Feldman, The Hydrologic Engineering Center, Corps of Engineers

David C. Curtis, International Hydrological Services

Darryl W. Davis, The Hydrologic Engineering Center, Corps of Engineers

Lewis Smith, Office of Chief of Engineers, Corps of Engineers

George Nicholas Fach, Jr., Baltimore District, Corps of Engineers

SUMMARY: RESEARCH NEEDS PANEL DISCUSSION

Several areas of research and development needs were identified during the seminar. The needs addressed policy, guidance, threat detection, response, evaluation, and training aspects of the system. It is, in fact, a system of such actions which are required to develop and operate a successful local flood warning-response project. Those aspects of a successful system are discussed in the following paragraphs.

Policy formulation and support are especially important in large organizations such as the Corps. The basic question is "how to sell such damage reduction measures within the Corps?" What authorizing legislation should be used? How can these additional data obtained for flood warning benefit investigations for more traditional projects? Also, show that these warning measures don't necessarily compete directly with other project benefits. Another important question is what liabilities are there to federal and local agencies? It was noted in this seminar that several levels of federal, state and local agencies may be involved; what are the best interagency relationships to foster sound projects? Should an interagengy committee be established to set uniform standards?

Guidance for these relatively new types of projects is critical to their success. Criteria need to be established to help select appropriate projects and their components. Examples of successful projects must be documented. Since much of the work and equipment may come from private industry, example scopes-of-work should be available to help agencies procure the needed materials and expertise. The multi-agency aspect of the project requires good information on how to best obtain state and local commitments to the project. Should the states' expertise be a central component? Many cities are most comfortable in working through their state agencies. The local agency (city or local flood control district) is the key to a successful project; how can these projects best be sold to them? The multipurpose nature of the data available in a flood warning system may be very attractive to several such agencies. Also, guidance will be needed to make effective working arrangements in this multi-agency environment.

Threat detection is the first component of the system. A variety of hardware (gages and computers) and software (procedures and computer programs) is now in use. The technology is quite young, however, and research is certainly needed to improve the existing capabilities. The main areas of interest are: data collection; data transmission; flood forecasting; decisions mechanisms; and information dissemination. Existing capabilities vary form high-tech satellite systems to simple staff gages read by a volunteer observer. Thus, a range of capabilities must be developed and their costs and performance documented so that the appropriate system can be designed for different users. Also, the appropriate level of technology for effective use by various local agencies needs to be identified. Should the techynology be kept in a "black box" or should the locals be cognizant of the inner workings of the threat detection/forecast system?

Preparedness plans are the next part of the system. Improved methods need to be developed for warning dissemination to, evacuation of, and re-entry to the flooded area. The key issue is how to keep the population cognizant of the plan and its operation in an emergency. The minimum requirements for a response plan should be identified. The best ways to utilize local resources and keep their interest in the plan are essential. Survey procedures, such as those used in the Corps' Baltimore Dist., need to be documented.

Evaluation is the final step of the project analysis. Standards need to be established to show how good a plan is and to identify/limit liabilities associated with it. A data base of successful plans/systems needs to be developed both as a measurement tool and as guidance for future projects. Simple (and as standard as possible) economic evaluation tools must be developed to evaluate the projects.

Training of personnel involved in these relatively new (or at least non-traditional) projects is essential to insure quality products. Training courses and documents are needed at both the managerial and technical levels. Study methodologies, equipment capabilities, software capabilities, technical support, management support, and evaluation methods all must be documented.

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