GUIDELINES FOR DEVELOPING A COMPREHENSIVE FLOOD WARNING PROGRAM

Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009
(602) 506-1501

January, 1997

This paper is modified from an original work by the Arizona Floodplain Management Association Flood Warning Committee
"Guidelines for Developing Comprehensive Flood Warning"
June 1996

GUIDELINES FOR DEVELOPING A COMPREHENSIVE FLOOD WARNING PROGRAM

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TITLE	PAGE

ACRONYMS

AAUG	Arizona ALERT Users Group
ALERT	Automated Local Evaluation in Real Time
AUG	ALERT Users Group (CA, NV, AZ)
COE	U.S. Army Corps of Engineers
CRS	Community Rating System
DCP	Data Collection Platform
EAP	Emergency Action Plan
EOC	Emergency Operations Center
FCDMC	Flood Control District of Maricopa County
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FPMS	Flood Plain Management Services
FTR	Flood Threat Recognition
LAN	Local Area Network
MIC	Meteorologist-in-Charge
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
NWS	National Weather Service
ORE	Other Response Efforts
PAR	Population at Risk
SAAS	Southwestern Association of ALERT Systems
USBR	U.S. Bureau of Reclamation
WAN	Wide Area Network

DEFINITIONS

ALERT - Automated Local Evaluation in Real Time: a hardware format developed by the National Weather Service so vendors could manufacture compatible flood warning equipment.

ALERT Base Station - The computer and communications hardware and software necessary to receive, store, display, analyze, and archive ALERT data.

Expert System - A software program running on the ALERT base station which analyzes data from multiple stations and can carry out a set of instructions based on programmed conditions.

FCC License - A License granted for each radio transmitter in the system by the Federal Communications Commission through the National Weather Service.

Flood Warning Plan - A procedural document developed by the community outlining causes and effects based on information from the Flood Warning System and other sources.

Flood Warning System - An integrated collection of data collection hardware and software, communications hardware and procedures, a maintenance strategy, and a Flood Warning Plan with the goal of protecting life and property from floods.

HEC-1 Model - A computer model used to predict streamflow magnitude at a point of interest. The model requires a number of inputs such as rainfall depth and duration, stream slope, soil water condition, infiltration rates, and others.

Permit - A long-term grant of permission or right-of-way given by the land owner for an ALERT station.

Pressure Transducer - An ALERT sensor used for measuring the depth of water.

Rainfall/runoff relationship - The ratio of rainfall volume to streamflow volume. The relationship varies with rainfall intensity and watershed characteristics.

Rating Curve - A graphical representation of water depth versus discharge or water depth versus storage (in the case of a dam)

Sensor - A mechanical or electronic device at a station which measures a specific hydrologic or meteorlologic parameter.

Stand pipe - An aluminum tube which encloses the ALERT transmitter and holds the tipping bucket sensor above the ground.

Station - A collection of sensors located at one site.

Staff Gage - any type of graduated markings placed on an object in flowing or static water from which the depth can be estimated by an observer.

Stage/Storage/Outflow curve - A graphical representation of the relationship between depth of water, the amount of water stored, and the amount of water released for a particular dam.

Tipping Bucket - A type of sensor which measures precipitation depth. Typically the "bucket" will tip each 1mm or .01 inch of rainfall, and the time of the tip is recorded by the base station.

Weather Station - An ALERT station which contains sensors for measuring at a minimum precipitation, wind speed and direction, temperature, and relative humidity. It may also measure barometric pressure, solar radiation, pan evaporation, and water temperature.

SECTION 1
INTRODUCTION

In recent years, there has been much progress in the development and implementation of local flood warning programs as a viable means of nonstructural flood control. Existing programs across the country offer a range of services and cover a variety of areas from very small to entire states. Despite vast differences in program components, there is one common frustration: the difficulty in progressing beyond collecting and monitoring data to actually removing people and property from a flood threat.

PURPOSE OF GUIDELINES

These guidelines are intended to serve two purposes: 1) to present the *total commitment* required to provide comprehensive flood warning services, and 2) to offer suggestions on how to develop a customized, comprehensive flood warning program. It is hoped that these guidelines will assist communities in the early stages of program development as well as those which have operational programs but have not yet developed comprehensive services.

INTRODUCTION TO FLOOD WARNING PROGRAM ELEMENTS

A complete flood warning program includes the development and coordination of three basic elements: 1) detection and evaluation of a flood threat, 2) dissemination of warnings, and 3) response to the warnings. A flood warning system must also account for potential failures in any of its components. Consideration needs to be given to planned redundancy and contingency in the system as backup in the event of a failure in any given functional area.

Successful flood warning must also include coordination between federal, state, and local government agencies and private sector organizations. As the system is used and tested, continual update and improvement of the flood warning plan is vital to maintaining an effective flood warning program.

Major components which must be addressed when planning and operating a comprehensive flood warning program include:

- Flood Threat Recognition
- Warning Dissemination
- Emergency Response
- Other Response Efforts
- Critical Facilities Planning
- Cost Components
- Maintenance
- Permits and Licenses

Each of these components is introduced on the following page. A more complete description is provided in later sections of these guidelines.

Flood Threat Recognition

A flood threat recognition system (FTR) is any system that is used to identify flooding severity. It can be as simple as 24-hour monitoring of the NOAA Weather Radio, or can be a complex system of hardware and software which transfers real-time data to numerous locations. The effort required to install and maintain the FTR is typically significant. However, it is only the first step in achieving the end result of saving lives and property through flood warning.

Warning Dissemination

Dissemination of flood threat information is only effective if the information is received *before* a particular flood threat is realized. Dissemination by public agencies other than the NWS usually entails notification of emergency management, public works, and other essential personnel so that preventative steps may be taken to minimize the impacts of flooding.

Emergency Response

Emergency response is the community's action plan to respond to a potential flood threat and minimize loss of life and property. Ideally, a community's emergency response plan is initiated before flooding occurs to receive the maximum benefit of flood threat data and to minimize flood damages.

Other Response Efforts

"Other Response Efforts" refers to portions of a community's emergency action plan not specifically tied to the flood warning program, which could significantly benefit flood fighting. Examples include identification of specific tasks to be performed and by whom, and an inventory of resources along with what might be needed to fight a flood.

Critical Facilities Planning

Critical facilities planning is coordination of warning efforts with facilities which may have special needs or deserve special attention during a flood. Critical facilities include police and fire stations, hazardous materials storage, public and private utilities, hospitals, nursing homes, and schools.

Maintenance

A commitment to regular maintenance is required for the successful operation of any flood warning program. Maintenance of the FTR must be performed periodically to minimize the occurrence of equipment failure during flood emergencies.

Cost Components

There are significant start-up costs to implement a flood warning program, and these costs vary widely according to the needs, size, and type of flood threat of the individual community. In addition to initial costs, there are significant operational and maintenance costs incurred and event driven costs during and after a flood event.

Permits

A wide range of permitting requirements may exist within a single flood warning program. Permits are typically required for the installation, operation, and maintenance of field equipment. Specific requirements and the time it takes to get authorization are different for every community. Depending on the existing land use and ownership, permits may be imposed by local, state, or federal agencies, Indian reservations, or private property owners.

CONTENT OF GUIDELINES

The remainder of these guidelines focus on the elements described above, and how each typically fits into a flood warning program. Also presented are time and cost commitments involved in developing and maintaining a flood warning program.

It is noted that these guidelines are organized in accordance with the credit evaluation criteria for Activity 610, Flood Warning, under the National Flood Insurance Program's Community Rating System (CRS).

SECTION 2
FLOOD THREAT RECOGNITION

The equipment used to detect and monitor flood threat forms the backbone of a flood warning system, and a wide variety of components are available for selection. A description of typical components are presented in this section.

IDENTIFICATION OF FLOOD THREAT CONDITIONS

When designing or expanding an FTR, it is necessary to first identify local flooding characteristics so that detection and monitoring components can be selected which are appropriate for the local flooding conditions.

Description of Watershed

A good physical description of the watershed is necessary to determine the types of flooding that occur, areas threatened, what type of equipment will work in a given area, and emergency response requirements. A sample description follows:

> "The 32.4 square mile watershed above Thunder Dam lies in east-central Arizona in eastern Maricopa and western Pinal Counties, with headwaters in the Thunder Mountains. Thunder river is the principal conveyance in the watershed - Loud Creek and Cloud Creek are the only named tributaries. The main and tributary streams convey runoff only during significant precipitation events, and during these times also convey large amounts of sediment to the Dam."

> "The watershed is divided into two physiographic units characterized by particular combinations or patterns of topography, soils, climate, water resources, land use and vegetative cover. The hills unit, approximately 12% of the watershed, is primarily rolling hills with tributary drainage patterns and low mountains with slopes ranging from 10 to 55 percent. The plains unit makes up approximately 82% of the watershed and is composed of tributary and distributary drainages with some low hills."

> "The average annual precipitation in the Thunder Dam watershed is about 15 inches. Annual rainfall is usually about equally distributed between the winter months of December through March, and the summer months of July through September. Daily precipitation of over three inches has been recorded. The area is characterized by high intensity, short duration thunderstorms during the summer months. These thunderstorms normally cover less than 100 square miles, and the intensity of rainfall can exceed one inch in one hour. The winter precipitation normally comes from general rain with much lower intensities than the summer storms. Snowfall is generally limited to trace amounts."

Type(s) of Flooding

Two types of flooding generally compel the installation of a flood warning system: flash floods, with peaks occurring in less than 6 hours, and/or rapid riverine floods, with times to peak from 6 to 48 hours.

Identification of Areas Threatened by Flooding

The area(s) affected by flooding should by shown on a map or otherwise described. The description should include information about the nature of the flood hazard, such as flood depths, velocities, warning times, historical flood problems and special hazards. The following types of information should also be covered: number, types and, if available, elevations of buildings; land use (residential, commercial, industrial, natural desert, etc.); critical facilities; and historic flood problem areas including health and safety hazards. An example paraphrased from the NFIP's CRS Coordinator's Manual is:

> "The City of Planton has three areas affected by flooding: the Planton River and Little Creek floodplains which are shown of the Flood Insurance Rate Map (FIRM) as "A Zones" and the Eighth Street drainage area, which is not shown on the FIRM. An inventory of these areas shows the following:
>
> - In the A Zones along the two streams there are 187 flood-prone buildings: 151 single family homes, 8 multi-family buildings with 32 units, and 28 business properties. Only 12 of these buildings have been built or improved since floodplain regulations went into effect in 1983. Many of the older buildings have basements.
> - There are 20 single family homes in the Eighth Street drainage area, all with basements.
> - The area subject to the greatest damage is the Little Creek floodplain upstream of Third Street. This area has 139 single family homes and two multi-family buildings.
> - All of the 28 businesses are located downstream of Third Street, with the greatest area of concentration between Third and Front Streets."
>
> "Six critical facilities exist within the three floodplains which deserve special attention because they are vital to the community or pose a special hazard during a flood. These are identified below:
>
> - A 100-year flood would damage the control and laboratory building of the City's wastewater treatment plant. The city would then be without sewage treatment for weeks.
> - Three bridges cross the two streams: State Route 41, Front Street and Third Street. The State Route 41 Bridge is high enough so it should still be usable during a 100-year flood, but it must be monitored to ensure that it is safe to use. The Front Street bridge is flooded during a 25-year flood and the Third Street bridge went under during the 1979 40-year flood. Closure of the two City

bridges isolates the northeastern 20-block area of town. Traffic can only reach this area by taking a two-mile circuitous route to the north that depends on the Highway 41 bridge being open.

- The City's Police and Fire Station is on the edge of the floodplain. A 100-year flood would cover Front Street to a depth of two feet in front of the station, cutting off vehicular access. It also probably would flood the building's basement, which includes the City's Emergency Operations Center (EOC).
- Chemicals stored in above-ground tanks at the Farm Service Company's agricultural chemical storage yard include fertilizers, pesticides, and herbicides, several of which are kept in toxic concentrations."

Required / Available Lead Time

The amount of lead time needed between the recognition of a flood event and the successful response to a flood warning greatly influences the type of FTR (flood threat recognition) system that is required. Studies of past flooding events show that the factors which most directly influence threat to human lives are the size of the population at risk (PAR), the amount of lead time prior to flooding, and the severity of the flooding event. Other key factors include previous experience with flooding and population density of an area.

The U.S. Bureau of Reclamation (USBR) has adopted procedures that estimate loss of life due to flooding based on the number of PAR, the amount of lead time, and adjustments due to local conditions. USBR's analysis of historic cases shows that for cases with lead time greater than 90 minutes, PAR is a very good predictor of loss of life. However, for lead time less than 90 minutes, other factors such as the time of day, the occurrence of prior flooding, and the severity of flooding have a greater influence on loss of life. USBR's studies emphasize the importance of lead time. Improving lead time to 90 minutes or more appears to reduce fatalities by over 90 percent.

A study performed at the Oak Ridge National Laboratory for the US Army Corps of Engineers Institute for Water Resources also showed that PAR is a good predictor of loss of life for greater lead time and that loss of life is greatly reduced with longer lead time. The Oak Ridge Laboratory's study also showed that population density of an area has a strong influence on loss of life. In less populated areas, the warning process is not as efficient in disseminating the warnings because of lack of public officials and resources and because there is a larger area to cover.

The available lead time for an area may be determined by hydrologic and hydraulic studies performed on observed records where available, supplemented by rainfall-runoff analysis of observed and hypothetical frequency events. Many technical manuals and computer programs are available to assist in performing the hydrology and hydraulics studies.

SELECTION OF APPROPRIATE SYSTEM COMPONENTS

A major issue surrounding monitoring and detection is how much information is needed to detect an impending emergency. The answer to this question hinges on a number of factors including the complexity of the watershed being monitored, the adequacy of scientific theory or intelligence to predict an emergency, the type of data assessment that must be performed, the level of confidence desired in that analysis, and the resources available to support detection and warning. These needs vary among flood types and locations.

Assistance in developing a flood warning program may be obtained from other agencies such as the National Weather Service (NWS) or the U.S. Army Corps of Engineers (COE), from private consultants (usually engineering firms specializing in water resources or vendors who sell flood warning equipment), and from professional organizations. In the western U.S., organizations such as the Southwestern Association of ALERT Systems (SAAS), the ALERT Users Group (AUG: CA, AZ, NV), and the Arizona ALERT Users Group (AAUG) all have members with experience in flood warning and are willing to share that experience.

Following is a list of components that may be used, all or in part of a flood warning system.

Observers

Volunteer observers and inexpensive equipment, such as plastic rain gages and box-cameras, are often the first and least complicated component of an FTR. Precipitation amounts and/or stream staff gage readings can be recorded and relayed to emergency personnel via telephone.

Automated Gages

The two basic types of automated flood detection gages are precipitation and water level. Many choices are available from various vendors for each type of gage. The final system design will be greatly influenced by the availability of funding.

Base Station Hardware and Software

Depending on the level of sophistication that is justifiable, the base station hardware can be as simple as a telephone instrument for receiving observer data or as complex as a computer-network based automated data receiving, storage and management station. There are also many hydrologic and hydraulic software packages and expert systems on the market for use in design, forecasting and/or operation of the FTR.

Radar and Satellite Data

The detection of the formation, approach, and passage of storm systems can play a major role in the early warning of a potential flood emergency. The primary precipitation detection systems are based on radar, satellite and lightning technology. Again, there is a broad spectrum of choices from simply looking out the window, for which there is no substitute, to a complete radar receiver site with computer, receiver and satellite dish. Other less expensive options include monitoring the Weather Channel ® on cable TV or a dial-up product to receive radar and satellite data via telephone modem into a personal computer.

Meteorological Support

Meteorological support in most cases is provided by the NWS in the form of weather forecasts, flood/flash flood watches, and flood/flash flood warnings. If more detailed or site-specific meteorologic information is required for providing an area with sufficient lead time to effect flood preparations, then adding a staff meteorologist or contracting with a meteorological consulting service are two options to consider.

Decision Aids

Once the data are available, how does the responsible agency determine when to issue a warning? The tools available to analyze the data range from a very basic manual system to a fully automated computer system. Manual systems could consist of tables, graphs and charts derived from average rainfall and flood indexes. Computer systems can include sophisticated data management, modeling, forecasting, and automated warning dissemination. Individual components from the basic to the complex may be fit together to satisfy the needs and constraints of a particular flood warning system, and many may be modified to improve the efficiency, reliability, and lead time provided by the system. A listing of some of these components follows:

- Quality control of input data
- Display of input precipitation data in tabular or map form
- Display of water-level data in tabular or graphic form
- Display of weather sensor data in tabular or graphic form
- Visual or audible alarms based on precipitation rates, height or rate-of-rise at a water-level sensor, windspeed threshold, etc.
- Hydrologic models - using real-time or predicted rainfall or hydrograph information as inputs
- Text and graphical histories of past events at specific gage sites
- An electronic link with the closest NWS office to receive forecast and warning products
- Radar and satellite products
- Weather and streamflow observers

Ultimately, a flood warning plan must be created to quantify the data parameters necessary for making warning decisions.

COMMUNICATIONS

There are three types of data transmission communications on the market today: telephone, radio, and satellite. The type or types used will be determined by the characteristics of the system such as topography, availability of equipment, available funds, and lead time.

Telephones

Telephones may be used by observers to call in data to a person, to a recorder, or to a computer by touch tone keypad input. They may be used at a remote location by automatic equipment to dial into a computer on a scheduled interval, or may be event driven. They may be used by a computer to interrogate field gages, and are a means of communication for warning of flood emergencies from the base station either by the computer or individuals monitoring the base station. The principal drawback is that phone lines often do not exist in remote areas where gages are needed. Also, telephone service frequently fails during severe weather and flood events.

Radio

Radios use UHF, VHF or microwave line-of-sight transmissions, often event driven, to transmit data to a computer base station receiver/decoder which converts the radio signal to digital format for use by the computer. In large drainage basins or areas without line-of-sight from the gage locations, repeaters may be necessary. Repeaters generally receive and transmit at different frequencies when they transmit data directly to the base station receiver, but may receive and transmit on the same frequency when relaying data to another repeater. The most common format for radio data collection in use across the western United States is Automated Local Evaluation in Real-Time (ALERT). The organizations listed on page 26 or any of the ALERT vendors may be contacted for detailed information about ALERT hardware and software.

Satellite

In large riverine drainage basins where lead times exceed 24 hours, satellite transmission of data may be a viable alternative. Satellite data are normally transmitted on a scheduled interval of several hours and therefore are less effective in rapid-response watersheds. In areas where line-of-site radio transmissions require an extensive system of repeaters and there are no telephone lines, satellite transmission may be the only solution. The USGS and COE use satellite data collection platforms extensively in their operations.

Redundancy

Redundant communications equipment is always desirable when critical data are involved. Redundancy can be achieved by combining any of the previous data transmission methods at a single collection site, for example, a cellular phone backup at a satellite site. At very critical gage sites, it may be wise to install two sets of gage equipment (transmitters, sensors, batteries) and receive data from both.

SECTION 3

WARNING DISSEMINATION

Flood warnings are issued to reduce the risk to life and property through public and private channels. Before warnings can be issued, information pathways to the end-users of the warnings must be identified and optimized.

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 the decision on whether or not to issue a warning (usually determined by preset criteria that is recognized by the FTR component), formulation of the warning message and identification of the appropriate audience, and means (radio, television, sirens, bull horns and door-to-door) of the 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 (i.e., mayor, law-enforcement personnel, fire fighters, designated block watch representative). The message, orally presented or distributed as a written handout, should state the time before the flooding occurs, its expected severity, and describe appropriated response actions (e.g., evacuation routes, safe shelters, protective actions).

IDENTIFICATION OF AGENCY GROUPS

The primary government agency responsible for flood warnings in the NWS. Existing local flood warning agencies rely heavily on interaction with the NWS for disseminating warnings to the general public. Very few, if any, local agencies warn the public directly. FTR and warning data are generally shared with the NWS via a local area network (LAN), dial-up connection, phone or fax, or by direct reception of the sensor data. Local agencies may provide FTR and warning data to state and local emergency management agencies, public safety agencies such as police, sheriff, and fire, and public works agencies such as street departments or hazmat teams.

Methods for communicating warnings to agencies and the public include broadcast via FM radio (in the case of NOAA Weather Radio), trailers on TV broadcasts, activation of the Emergency Broadcast System, telephone trees, single site or broadcast fax, transmission of computer files over modem, LANs, or wide-area network (WAN), and two-way radio.

IDENTIFICATION OF TARGET PUBLIC GROUPS

In most cases, flood warnings to the general public are left to the NWS. However, in some cases "target" groups are identified in areas which share a common serious flood threat and which might be missed by the casual TV watcher or radio listener. In these cases, a warning is first communicated by a public official by any of the above means to one or more designated individuals in the group. The designated individual then initiates an existing dissemination plan to warn the other group members. That plan could for example be a phone tree or a person physically traveling from house to house.

PUBLIC EDUCATION PROGRAM

When developing any warning dissemination program, public education should be addressed. Public education serves two purposes. First, a community that is aware of flood dangers will be less likely to require emergency rescues. Second, education will assist warning dissemination efforts because the public will have been informed on where to turn for flood information, what the warnings mean, and what actions to take. A continuing public education program is particularly important in communities which experience transient population trends, have infrequent floods, or both. Typical elements of such a program are discussed below.

News Media

The local news media can be an excellent format for public education programs. Local television and radio stations can participate in public service messages timed to be aired prior to the flood season(s). Additionally, one radio and one television station might be designated as a public source of flood threat information. It is also beneficial to establish a relationship with the local news media so that during a flood, they can assist in the dissemination effort rather than distract emergency response staff and possibly hinder response efforts.

Videos

A professionally-produced video can be very useful in educating the public to local flood dangers. The video can be made available to various community groups including schools, colleges, libraries, homeowners associations, block watches, professional organizations, and others. It may be possible to enlist a local television or radio personality to narrate the video, thus increasing its credibility and professionalism in the public's eyes.

Pamphlets

Dissemination of flood threat information to the public in a non-emergency format can be easily and cheaply done through pamphlets. Material can include some simple definitions, what to do in case of a flood, and where to turn for additional information during an emergency or non-emergency. Pamphlets can be distributed at local schools, libraries, community centers, government offices, and special events such as shows and fairs.

Children's Material

Many communities have developed children's material to educate them about the dangers of flooding. The most popular formats are coloring books and comic books. These materials can be distributed at local schools, libraries, government offices, and special events. Other programs could be developed for children in conjunction with printed material, such as preparing a talk on flooding to address groups such as boy/girl scouts or individual classrooms.

SECTION 4
EMERGENCY RESPONSE

The essential element of warning dissemination for any community is a working Emergency Action Plan (EAP). Most communities have in place an EAP which covers many types of emergencies, including floods. However, the information may not be as specific to flood threat as desired. In order to assess its effectiveness from a flood warning operator's perspective, a few basic questions should be asked:

- What are the goals of the EAP?
- What are the goals of the flood warning program?
- Do the procedures in the EAP for flood emergencies meet its goals or the goals of the flood warning program?
- What is the outcome of acting on the procedures identified in the EAP?
- Is the EAP reactive or proactive?

DEVELOPMENT OF AN EMERGENCY ACTION PLAN

In answering the questions above, three major tasks are identified for developing or customizing an EAP. These tasks are identified and discussed below.

Identify Goals of Emergency Response

The first step in developing or revising emergency procedures is to identify the goals of the existing EAP. Consider what the current EAP will cause the emergency manager to do (e.g., monitor flood hazards, contact personnel). Is the action consistent with the established goals?

Second, the flood warning program goals should be identified. These goals are typically to move people and property out of harm's way prior to a flood event. Are these goals met by an existing EAP?

Finally, once the EAP and flood warning program goals have been identified, the flood hazards should be identified as well as any operational or response constraints. Examples of response constraints may be a severely short time between flood detection and flooding, access to certain areas during severe storms, or distance between emergency resources and the flood hazard area.

Specific structures which require monitoring or areas affected by riverine or flash flooding should be inventoried. The means to achieve the goals for each hazard can be established, as described herein.

Identify Lines of Communication

It will be necessary to identify what lines of communication and what actions would achieve the flood warning program goals. For example, in order to provide flood warning services downstream of a dam, the following lines of communication and necessary steps could be required:

1. At some point, a flood threat is recognized and the dam operator is notified.
2. Inundation maps and other available data are retrieved.
3. The dam operator notifies an on-call crew.
4. The on-call crew drives to the dam and reports in at regular intervals by radio, with a cellular telephone as backup.
5. The crew reports any noticeable problems (e.g., piping on the face of the dam, clogged outlet, rapid rise in water-level) as they occur.
6. Observed problems trigger mobilization of emergency crews and possible evacuation procedures.

Once communication needs are established, a detailed plan can be developed to include names, telephone numbers, and duties of the appropriated staff, as well as methods of communication.

Develop Criteria for Emergency Response

In order to provide consistent response and minimize chaos during a flood emergency, it is advantageous to develop pre-set criteria to act as triggers during a flood threat. For example, response to a dam emergency could be triggered by water-level, rate of change of water-level, or by a special problem such as piping. Flood response along a river or channel could be triggered by a water-level reading (which might also indicate a hazardous velocity) or results from a hydrologic model simulation using real-time precipitation data.

It is helpful to summarize all calculations and decision triggers in a chart which shows situation versus action. A simple graphical summary is very useful in emergency situations and the decision-making and response time is reduced.

Although consideration should be given to basing response decisions on real-time or model output, it should be recognized that model output data are less accurate, and confidence in the results should be correspondingly lower. In addition, it is very important to verify the stage data or hydrologic model data. A rating curve should be established for water-level gages and revised as appropriate (i.e., when a runoff event scours or fills a channel bottom or when direct or indirect measurements are made). Hydrologic models should be carefully calibrated using data from previous flood events.

INCORPORATION OF FLOOD WARNING IN AN EMERGENCY ACTION PLAN

In preparing these guidelines, it was assumed that an EAP already exists for an individual community. Therefore, the existing EAP would already have in place the following necessary components:

- Identification of the designated head of Emergency Management and backup personnel
- An organization chart which identifies responsibilities of designated staff

- Inundation maps for various flood stages
- Location and policies of the EOC
- Identification of outside agency coordination (local, state and federal)
- Identification of post-emergency activities

If not already part of the existing EAP, flood warning program activities should be incorporated. The portion of the EAP which covers floods could be enhanced, or perhaps an appendix specific to flood warning and flood emergencies could be attached.

It is more advantageous to work within an existing EAP and not develop an independent document for the following reasons:

- No separate ordinance or approval is required for an existing EAP which has already been adopted
- Staff has familiarity with the existing EAP and its procedures
- The EAP will have been tested and is a "known commodity"
- There would be a mechanism already in place for periodically verifying and updating information such as contact names and phone numbers
- The original authors of the EAP might be helpful in creating the flood warning section/appendix

MAINTENANCE OF AN EMERGENCY ACTION PLAN

Like flood warning equipment, emergency response activities require periodic maintenance to verify that the components will work in a real emergency. It is essential to any program that practice drills are held at least annually in years where no flood occurs. Also, the EAP should be updated periodically, at least annually, to include any changes in staff, telephone numbers, and responsibilities.

It can be very helpful to invite outside agencies to participate in periodic drills. Inclusion of outside agencies (e.g., a city participates in the county's drill) is a better simulation of actual flood emergency situations and can help the flood warning operator better identify areas where the EAP should be enhanced. After a drill is completed or a flood occurs, it is important to hold debriefings and implement any necessary changes which may have been discovered.

SECTION 5
OTHER RESPONSE EFFORTS

One of the most challenging tasks in preparing an emergency response plan is to identify tasks and responsibilities which are specific enough to be useful, yet are not so specific that they become quickly outdated or do not allow the flexibility needed in an ever-changing emergency situation. Theoretically, an emergency response plan would address all emergency situations. In addition, the response plan should accommodate resource information which could be easily retrieved in an emergency. Suggestions to accomplish these goals are identified in this section.

FLOOD-SPECIFIC RESPONSE PLAN

A community's emergency response plan should include a separate section for flood emergencies. Each major task would be assigned to an office, department or individual. It is important that, in large organizations, an individual be identified as the person responsible for communication with other departments, as well as carrying out the task. A typical flood response section would address the following:

- What are the specific tasks to be performed?
- Who is responsible for each task?
- What is the method of communication?
- What are the names and phone numbers (including backup persons) of responsible parties?

Summary Comparison of Resources

For each task in the flood response plan, it is very helpful if a summary comparison of resources is kept on file. Data to be collected include a list of what resources are needed to complete each task, the time required to perform the task, and the source(s) available to complete each task. For example, if a dike requires sandbagging during a flood, required tasks could include:

1. Notify the designated responsible party
2. Pick up the sandbags
3. Deliver the bags to the sand source
4. Fill the bags
5. Deliver the bags to the dike

Who performs these individual tasks? Where are the bags stored and where is sand available? Are there volunteer organizations (e.g., homeowners association, block watch groups) on-call to assist in the labor-intensive task of filling sandbags? These activities should be set up in advance in order to quantify needs and resources to better handle a flood emergency. A sample summary (Table 1) is presented which could be used to quantify needs and resources in advance of a flood emergency.

TABLE 1
Sample Comparison of Resources

EAP Task	*Responsible Party*	*Phone No.*	*Required Resource*	*Location*	*Alternate Location*
6.1	Joe Jones	555-4464	Sand Bags	DOT Yard	City Yard
7.3	Tim Thomas	555-3278	Loader	DOT Yard	FCD Yard

SECTION 6
CRITICAL FACILITIES PLANNING

Critical Facilities Planning is the coordination of warning efforts with facilities which may have special needs or require special attention during a flood. Critical facilities include police and fire stations, hazardous materials storage, public and private utilities, hospitals, nursing homes, and schools.

It is important to identify critical facilities in order to provide timely evacuation if necessary. Obviously, it is very important to maintain an up-to-date, accurate list of individuals to contact in case of an emergency, including names and phone numbers of backup personnel.

A community could require that an individual emergency response plan be developed for critical facilities. This could be developed by the critical facility and reviewed by the agency, or developed for the facility by the agency. An advantage of individual response plans for critical facilities is that during an emergency, required effort by the emergency response team is reduced because the critical facilities are performing some or all of the response themselves. This does create additional effort in setting up and/or maintaining the individual response plan, but alleviates the drain on resources during the actual emergency when those resources are in highest demand.

Annual emergency drills should be a requirement of any individual response plan of a critical facility.

SECTION 7
MAINTENANCE

The two basic types of remote flood warning systems - manual and automatic- vary in cost and complexity from a simple hand-held measuring device to more sophisticated sensors that automatically gather and transmit data from remote locations. Maintenance of the different types of systems will also vary, but the same basic principles apply to both.

A manual system might consist of a simple measuring device - a gain gage or staff gage - usually monitored by a volunteer and the data are relayed via telephone or radio (CB or ham). An automatic system might consist of a sensor (precipitation or stage), encoder, and a radio or Data Collection Platform (DCP). The DCP is usually powered by a solar-charged battery system and the data are transmitted through an antenna specifically designed for that particular radio-telemety system. Maintenance of the more complex system is naturally more comprehensive and more expensive.

Any gage that is part of a flood warning system should be checked daily for proper operation. If the gage is at a remote location and cannot be easily examined, the data from that gage should be verified each day. A preventative maintenance schedule should be devised that will ensure proper operation of the gage during a flooding situation. Typically, a file is kept for each station listing the directions to the site, station equipment, service history, etc.

The processing equipment, or base station, receiving data from the remote site should also be checked daily and should also have a preventative maintenance schedule that ensures proper operation when it is most needed. Redundant systems should be considered and service maintenance contracts could provide some of the needed preventative maintenance.

An agency should keep enough spare parts readily available to create, or repair, at least one complete remote site, and any radio-relay sites. Standardization of all components will reduce the costs of inventory. The items that require replacement more frequently (solar panel, battery, and antenna) should be stocked in larger quantities, depending of the number of stations in the system and the availability of those items.

The degree of vandalism at remote gage sites is usually dependent on the location of the site and therefore the visibility of the gage. There are many methods of protecting equipment against vandalism (fences, plating, camouflage, enclosure within buildings), but these measures must be weighed against the value and ease of replacement of the equipment. Remote stations in heavily used areas will likely require more attention.

If the FTR system data is collected by a central base station computer or network, then maintenance is required here also. The database can be periodically checked for bad data, have missing data restored if it is available, and be archived for future use. A backup computer or components (hard drive, network card, power supply) and uninterruptable power source are also good ideas.

SECTION 8
PERMITS

Installation of flood warning equipment on lands used or owned by other agencies or private parties will most likely require a permit to allow permission to install, maintain and operate a flood detection station. Agencies installing flood detection stations should seek legally binding permits because they guarantee long-term use and access to the site. Types of permits, the time required to secure a permit, and typical permitting requirements are discussed in this section.

TYPES OF PERMITS

There are generally two types of land use permits: one for government-owned or managed land and one for privately-owned land. Examples of the first type include those granted by the U.S. Forest Service, Bureau of Land Management, State, Counties, Indian Reservations, military bases, and railroads (although railroads are not government agencies, permit requirements are similar). These agencies usually have a Real Estate or Land Management department and have existing permit forms specifically for structures sited on their lands. If flood detection equipment is located within a designated floodplain or Special Flood Hazard Area, then a floodplain development or use permit may be required. There is usually a fee involved in obtaining a government permit, either a one-time fee, an annual fee, or both.

For the second type of land use permit, where stations are sited on private land, it is helpful to develop a permit form for the property owner to sign. In many cases, on private land, authorization can be obtained at little or no cost, and a private site can offer the advantage of information exchange over time with the property owner. Some landowners may hesitate to grant permission to locate equipment on their property if they feel they are being forced to cooperate or if they are concerned that they will not be able to change their mind at a later date. In these instances, it is helpful to note in the permit that the landowner has the authority to cancel the permit with a reasonable allowance for equipment retrieval.

Another required permit involves the licensing of any radio equipment in the system, and the assignment of a radio frequency(s) to the system. Radio licenses and frequencies are granted by the Federal Communications Commission through a federal sponsor. The Meteorologist-in-Charge (MIC) or the Service Hydrologist at the nearest NWS office can provide guidance for securing this license. Other assistance may be available from federal agencies such as USGS, USBR and the US Forest Service.

TIME REQUIREMENTS TO SECURE PERMITS

The permit process can and usually does take a considerable amount of time, varying anywhere from a couple of weeks for a private party to a year or more for some federal agencies. Depending on conditions at the site, a government agency may require inspection by utilities, an archeologist, a botanist, or an environmental engineer. These stipulations take time to fulfill. It is a good idea to begin the process of procuring permits as soon as station sites are selected so that they are in place when equipment is ready for installation.

TYPICAL PERMITTING REQUIREMENTS

Following is a list of information which is typically required when filling out a permit application for a government agency:

1. The name, address, and authorized agent of the applicant.
2. A brief description of the overall flood warning system and its purpose.
3. A detailed drawing or picture of the equipment being installed and a description of its function.
4. A map showing the station location and access routes.
5. A legal description of the site (i.e., township-range-section, latitude/longitude, or both) and elevation.
6. The expected period of the equipment will be in place.
7. Any expected operation and maintenance activities, their duration, and their frequency.
8. Any possible effects on wildlife or the environment, with documentation.
9. A statement of financial and technical ability to construct, operate, maintain, and terminate the proposed equipment.
10. Benefits (non-monetary) to the agency, environment, and public.
11. Opportunities for the agency to access or retrieve data collected at the site.

For private land use permits, it is also helpful to provide the information listed in items 1-8 above.

SECTION 9
COST COMPONENTS

An overview of cost components incurred in the implementation of a flood warning system is presented in this section. Actual dollar amounts have not been included because flood warning program needs are unique to each community and are affected by the size, complexity and type of flood threat on the watershed. Instead, cost components within a typical program are identified and are categorized as follows:

- Initial costs to investigate, design, and implement the plan components
- Annual costs to maintain the program components in a state of readiness
- Event-driven costs to implement specific actions during and after a flood
- Capital costs for replacement, upgrades, and expansion.

Information is also provided on potential sources of technical assistance and system funding at the federal, state, and local levels.

INITIAL COST COMPONENTS

The first step in establishing an effective flood warning capability is the development of a comprehensive flood warning plan. The objectives are to perform an evaluation of the community's flood warning needs versus resources, to establish procedures which address those needs, to design a suitable flood warning system, and to develop funding strategies for system implementation.

The initial costs associated with the development of the flood warning plan are predicated on the detail and complexity involved, and may involve personnel costs and/or fees for professional services to perform the initial plan development. The cost of a flood warning system must be evaluated in conjunction with the benefit to the community in reducing personal and property damage.

As previously stated, the FTR component can range from basic operations such as 24-hour monitoring of the NOAA Weather Radio to a complex system of hardware and software which transfers real-time data to numerous locations. Clearly, associated costs vary significantly with the type and level of FTR selected as part of the overall flood warning plan. If the FTR component is comprised of a network of flood detection hard/software, the initial costs are significant. Additional costs are incurred in the necessary task of acquiring an inventory of spare parts and materials. Once the equipment is purchased, costs will be incurred to install the system, provide training, and obtain hardware/software technical service.

Less expensive detection options could be used in lieu of, or in conjunction with, flood detection equipment in the field. These options include, among others, acquiring access to available data from regional detection networks operated by other agencies or the development of a local cooperative observer network. The combination of flood prediction and detection options which fit a community's needs and resources would be determined during the development of the flood warning plan. Cost considerations must be addressed at that time.

The need for meteorological support should also be assessed. In addition to NWS flood forecasts, watches, and warnings, more localized information may be available from public and/or private sources, or in-house forecasting capabilities may be established. The choices made regarding the type and complexity of data required directly impact the associated costs. Another factor to consider is that, in general, meteorological data can provide greater lead time but with reduced accuracy.

Warning dissemination is triggered by the recognition of an imminent flood event. Affected areas must be quickly determined and affected parties identified so that vital information can be communicated to them and appropriate response measures activated per the flood warning plan. Initial costs are those incurred to establish communication links with the appropriate parties and develop flood warning products that will be transmitted via those links. Again, costs are directly related to the level of sophistication required to meet the needs and fit the resources of the particular community.

The initial costs of the emergency response component are those incurred to allocate or acquire the necessary personnel, equipment, and financial resources to meet the needs identified in the flood warning plan. A detailed response plan must also include provisions for proper coordination between federal, state and local government agencies and private sector organizations. Costs are incurred in providing initial personnel training and in agency coordination activities. However, emergency response costs are often considered in-kind services and are not directly attributed to flood warning program costs.

Finally, permit and/or license fees will most likely be required for installation and use of field and base station equipment.

ANNUAL COST COMPONENTS

The flood warning plan is considered a working document which benefits from periodic review and evaluation as the system is implemented and becomes fully functional. Required updates and/or improvements to any component(s) should be identified as the system is used and tested during simulated or actual flood emergencies. The goal is to optimize the effectiveness of the flood warning capability. Annual costs for flood warning plan management include the cost of the time spent in evaluating the system and the cost of implementing any recommended improvements.

The FTR component requires regular maintenance of field equipment and possibly replacement. The periodic evaluation of the overall effectiveness of the flood warning plan may lead to equipment upgrades and/or additional installations at new sites to expand the network or to develop system redundancy. As a result, periodic replacement or supplementation of spare parts require expenditures. Annual operation and maintenance costs vary with the amount and type of detection equipment involved.

Annual costs associated with the FTR can include the acquisition of hydrometeorological data and forecast products from public or private sources or the cost to maintain in-house meteorological capabilities. Another potential cost can include developing/refining hydrologic and hydraulic models for use in predicting lead times and determining high-risk flood areas. this information directly impacts the warning dissemination and emergency response components of the flood warning system.

In addition to annual costs for equipment, costs are associated the management, processing, quality control, storage, and maintenance of the database created from the detection data.

Annual costs are incurred to operate, maintain, and upgrade the communications equipment of the warning dissemination component. Additional costs can be incurred to modify the communications network to develop system redundancy. Similarly, expanding the group of warning message recipients and/or warning products will most likely add to the cost.

Another important (and often overlooked) element of warning dissemination is the development of public awareness programs to inform the public about local flood hazards and the flood warning system. The development and distribution of public information products is a necessary annual cost. Such products include public service announcements for radio and television, educational videotapes, pamphlets, and brochures.

Annual emergency response costs are similar to the initial costs in that the periodic evaluation of the flood warning plan could lead to adjustments and improvements to the number of necessary personnel, equipment, and financial resources. Also, some costs would be incurred in staging regular training exercises and periodic drills.

Finally, in addition to initial permit and/or licensing fees, annual fees may be imposed.

EVENT-DRIVEN COSTS

During a flood event, certain vital services will need to be provided on a 24-hour basis. These may include:

- Temporary evacuation
- Search and rescue
- Mass care center operations
- Public property protection
- Flood fighting
- Maintenance of vital services

The emergency response personnel responsible for providing these services are sheriff, police, fire departments, emergency operations centers, and relief organizations. It is difficult to distinguish between local flood warning response plan cost items that fall under existing agency operations and those activated during a flood emergency which are otherwise tracked.

The following is a partial list of additional costs a community could expect in the event of a flood emergency:

- Personnel overtime and emergency hiring
- Equipment purchase and/or rental
- Transportation and storage of public property
- Material and supplies consumed during response efforts

The post-flood recovery effort would vary for each event and for each community. A partial list of post-recovery elements follows; each is a potential source of event-driven costs:

- Evacuee return
- Debris cleanup
- Return of services
- Damage assessment
- Provisions for assistance

CAPITAL COSTS

Time, mother nature, and unwelcome human interaction often make it necessary to replace system components at random intervals. Techlology marches on, often producing superior and therefore desireable equipment or software. And, many times after a system is established and tested additional desireable station sites are identified and require eqipment.

POTENTIAL SOURCES OF FUNDING AND TECHNICAL ASSISTANCE

There are several potential funding and technical assistance sources available on the federal, state, and local levels, as described below. It is important to understand that funding is nearly always through cost-share agreements where the local community must fund a portion of the costs and also agree to operate and maintain the system once it is installed.

U.S. Army Corps of Engineers

The Corps can assist communities in two ways: 1) provide technical services and planning guidance on floods and floodplain issues; and 2) provide emergency flood fighting during an event when the situation is beyond the resources of the state.

The Corps' Flood Plain Management Services (FPMS) staff are available to assist federal, state, and local government agencies and others in implementing flood warning /preparedness programs. The focus is to define the existing conditions and arrangements, postulate potential enhancements, and evaluate and recommend specific actions.

The investigation of flood warning/preparedness programs is covered under existing authorities and Corps regulations related to the FPMS program. Under this program the Corps is authorized, upon request by other federal and non-federal entities, to provide a full range of technical services and planning guidance on floods and floodplain issues under the general umbrella of floodplain management. Flood warning/preparedness planning is included in these services.

The Corps also provides emergency response (flood fighting) during flood events, but does not become involved until after a state or presidential declaration has been made. Typical flood fighting activities performed by the Corps or its pre-selected contractors include sand bag placement, remedial repair of levee breaks, or raising levee height. In the case of a presidential declaration, the Corps may become involved as part of the federal response plan coordinated by the Federal Emergency Management Agency.

National Weather Service

The NWS is a key resource for technical assistance in developing and operating a flood warning program. The NWS has been authorized by Congress to issue meteorological and hydrologic forecasts, flood watches and flood warnings. To accomplish its mission, the NWS gathers data from a variety of sources and uses that information to determine the potential hazard for any given area from events such as tornadoes, severe thunderstorms, winter storms, and floods. A partial list of information sources includes surface observations, balloon observations, severe weather spotters, law enforcement agency reports, pilot reports, remote automatic sensors (such as ALERT, IFLOWS, and USGS DCP), and radar and satellite images.

The NWS produces and issues various hydrometeorological forecasts and warnings. These include routine forecasts, special or severe weather forecasts/warnings, and stream and river forecasts. Additionally, NWS receives vast amounts of outside agency hydrometeorological data and makes that data, as well as NWS data, available to users.

National Resources Conservation Service

The National Resources Conservation Service (NRCS) recognizes the use of flood warning systems along with other nonstructural and structural measures as means of reducing flood damages. NRCS can provide both financial and technical assistance to develop and install local flood warning systems.

In watersheds less than 250,000 acres in size (Public Law 566), NRCS can fund up to 80% of the installation costs for a flood warning system. Similar funding authorities are available under the Resource Conservation and Development Program. Because the principles and guidelines of this program are applicable to the watershed program, flood warning systems must be economically justified to be eligible for cost-share assistance. Cost-sharing may be provided for the installation of rain and/or stream gages, radio relay equipment, a computer or analysis system, and a warning dissemination system.

The NRCS may participate in pilot projects to demonstrate new technology or to gain acceptance of innovative approaches using special limited funds available under the Resource Conservation Act.

State and Local Agencies

Funding and technical support on the state level varies from state to state, but typically includes state departments such as Water Resources and Emergency Management. Valuable technical assistance can be provided to procure, install, and troubleshoot equipment and to provide training on the operation of equipment, and emergency response training. Maintenance agreements may also be valuable.

Similar technical assistance may be available from local agencies with operational systems such as flood control districts or nearby cities. Exchange of information is very helpful, programming support may be available, and maintenance agreements can be economical, depending on the relative locations of flood warning program boundaries.

Professional Organizations and User Groups

Technical assistance can also be obtained from regional and local professional organizations and user groups. Following are some suggested resources:

Ms. Laurie Miller
Chair, Flood Warning Committee
Arizona Floodplain Management Association
c/o Montgomery Watson
(602) 954-6781

Mr. Dennis Gibbs
President, California ALERT Users Group
c/o Santa Barbara County Flood Control District
(805) 568-3440

Mr. Jim White
President, Southwestern Association of ALERT Systems
c/o Harris County Emergency Operations Center (Houston)
(713) 881-3078

Mr. Chris Crompton
Representative, National Hydrologic Warning Council
c/o Orange County Department of Public Works
(714) 567-6360

Mr. Steve Waters
Arizona ALERT Users Group
c/o Flood Control District of Maricopa County (Phoenix)
(602) 506-1501

SECTION 10

SUMMARY

A common frustration among operators of flood warning systems is the difficulty in evolving from a data collection and monitoring system to one that saves lives and property form flood threat. These guidelines offer a description of the total commitment required to develop comprehensive flood warning services, and suggestions on how this goal may be achieved.

A complete flood warning system includes careful design and planning, equipment maintenance, flood detection, evaluation of the flood threat, timely dissemination of flood warnings to the proper recipients, and the correct response to those warnings. This paper presented a broad range of system components so that individual communities could use the in accordance with their specific needs, opportunities, and constraints.

Cost components were identified which would need to be considered when seeking funding for a flood warning program. Actual dollar amounts were not included because specific needs are unique to each community and are influenced by the watershed size, complexity, and type of flood threat. Costs were identified as initial, annual, and event driven. Finally, funding and technical support sources were identified to assist in financing and operating a flood warning program.

It is hoped that those considering creating a flood warning program will gain a better understanding of the steps involved in program implementation and those already involved may discover some areas of improvement for their existing programs.

REFERENCES

Arizona Floodplain Management Association Flood Warning Committee, "Applying for CRS Flood Warning Credit: It *Can* Be Worth It", 1994.

Curtis, David C., "The Cost of Flood Warning Systems", presented at the Conference of the Southwestern Association of ALERT Systems, October 1994.

Federal Emergency Management Agency, "National Flood Insurance Program Community Rating System Coordinator's Manual", June 1993.

George V. Sabol Consulting Engineers, Inc., "Statewide Hydrologic Data Collection/Dissemination Network", Flood Control District of Maricopa County, Arizona, 1995.

Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data, "Guidelines on Community Local Flood Warning and Response Systems", 1985.

Mileti, Dennis S. and Sorenson, John H., "Communication of Emergency Public Warnings", 1990.

Montgomery Watson, "Flood Warning Services Market Survey Study", Flood Control District of Maricopa County, Arizona, 1990.

U.S. Army Corps of Engineers, "Arizona Flood Control Study, Arizona - Reconnaissance Report", September, 1994.

U.S. Army Corps of Engineers, "General Guidelines for Comprehensive Flood Warning /Preparedness Studies", 1988.

U.S. Army Corps of Engineers, "Proceedings of a Seminar on Local Flood Warning - Response Systems", 1986.

U.S. Water Resources Council, "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies", 1983.

Urban Drainage and Flood Control District, "Ralston Creek Flood Warning Plan, City of Arvada and Jefferson County, Colorado", 1994.